

This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



Mechanical Engineering of Collieries

C. M. PERCY

HADFIELD'S STEEL FOUNDRY Co

ATTERCLIFFE SHEFFIELD.

STEEL CASTINGS

SOUND TOUGH DURABLE

CONTRACTORS TO H·M·HOME INDIA & COLONIAL GOVERNMENTS

HOME, FOREIGN AND COLONIAL RAILWAY ADMIRALTY·WAR DEPARTMENTS &c.



GOLD MEDAL 1881 MELBOURNE

GOLD MEDAL 1883 MADRID

GOLD MEDAL 1878 PARIS

DIPLOMA OF HONOR SYDNEY 1879

GOLD SILVER MEDAL 1884





The wheel shown on above anvil has been tested with 40 swinging blows of a 14lb. sledge hammer, and only bent as shown.

SOLE MAKERS OF

HADFIELD'S CAST STEEL WHEELS

ROLLERS, PULLEYS, PEDESTALS, AXLES, &c.

FOR COLLIERIES, TRAMWAYS, RAILWAYS, IRONWORKS, IRON-STONE, LEAD, TIN, COPPER, SULPHUR, SALT, GOLD & OTHER MINES CHINA CLAY WORKS, BRICKYARDS, &c

Our simple and effective Patent method of fitting up wheels and axles secures freedom, both from wheels working loose and breakages. We only manufacture the first quality, and in addition to the now universally admitted superiority of Hadfield's Steel Wheels over those of cast iron for lightness, strength and wearing qualities, it has been proved that our wheels also possess the following advantages over any other steel, malleable iron or other wheels, viz :—EXTRA TOUGHNESS, TENACITY, DURABILITY & SOLIDITY

The best proof of this is that we have now in daily use, and giving every satisfaction MORE THAN

ONE-AND-A-HALF MILLION.

We also solicit attention to the following articles, which, in addition to our well known Patent Steel Wheels and Axles, we are now largely supplying in our CAST STEEL, on account of their great strength combined with durability and lightness:

Rollers, Pulleys, Angle Sheaves, Frames Stands, &c.—for use of over 100 different patterns. They possess great durability, lightness, and strength, and add immensely to the life of the tramway or other traffic.

Self-oiling Wheels (Patent)—Many thousands now at work, there at least 50 per cent. of oil is saved. Easily changed or re-filled. Reduces friction and wear and tear to a minimum.

Pedestals, Brakes, Cage Guides, Roller Boxes, Points, Crossings, Wedges, and other Steel Colliery Castings and Forgings of every description.

Over 1000 different patterns of above in stock, ready for use on the shortest notice. New patterns made to suit special requirements free of charge for quantities.

Steel Axles, we turn all classes of bearings, of our special mild and close quality, standing 50 tons tensile strain with proper limit, elongation and symmetry, equal resistance of thickness to bend and so giving steady satisfaction.

Steel Coupling of all kinds. Machine moulded or brass fast per metre, also the new Bonnet Cap Wheels.

Miscellaneous Steel Castings, up to 10 cwt. in one piece, to replace expensive wrought-iron and steel forgings and bored true castings.

Also—Gudgeons of tapering and cranc revolutions, we are the sole manufacturers of this important revolving work. See Specimens view Hadfield's names to on every wheel.

The above stands above a [illegible] specimens [illegible] full size, turned out of one of Hadfield's unbreakable Steel Castings, tested by E. H. Gove, and stood all tests and conditions, breaks strokes, and 20 per cent. elongation. Our new material, and Second Steel Castings are selected to ensure chemical analysis, and tested for mechanical strength by E. H. Gove, Kennedy, Admiralty Proofs, Kirkaldy, Washington, &c., giving results of from 30 to 35 tons per square inch, combining ductility to complete requirements and up to 30 per cent. elongation.

OVER 1100 DIFFERENT WHEEL PATTERNS IN STOCK



HECLA STEEL FOUNDRY

STEEL CASTINGS

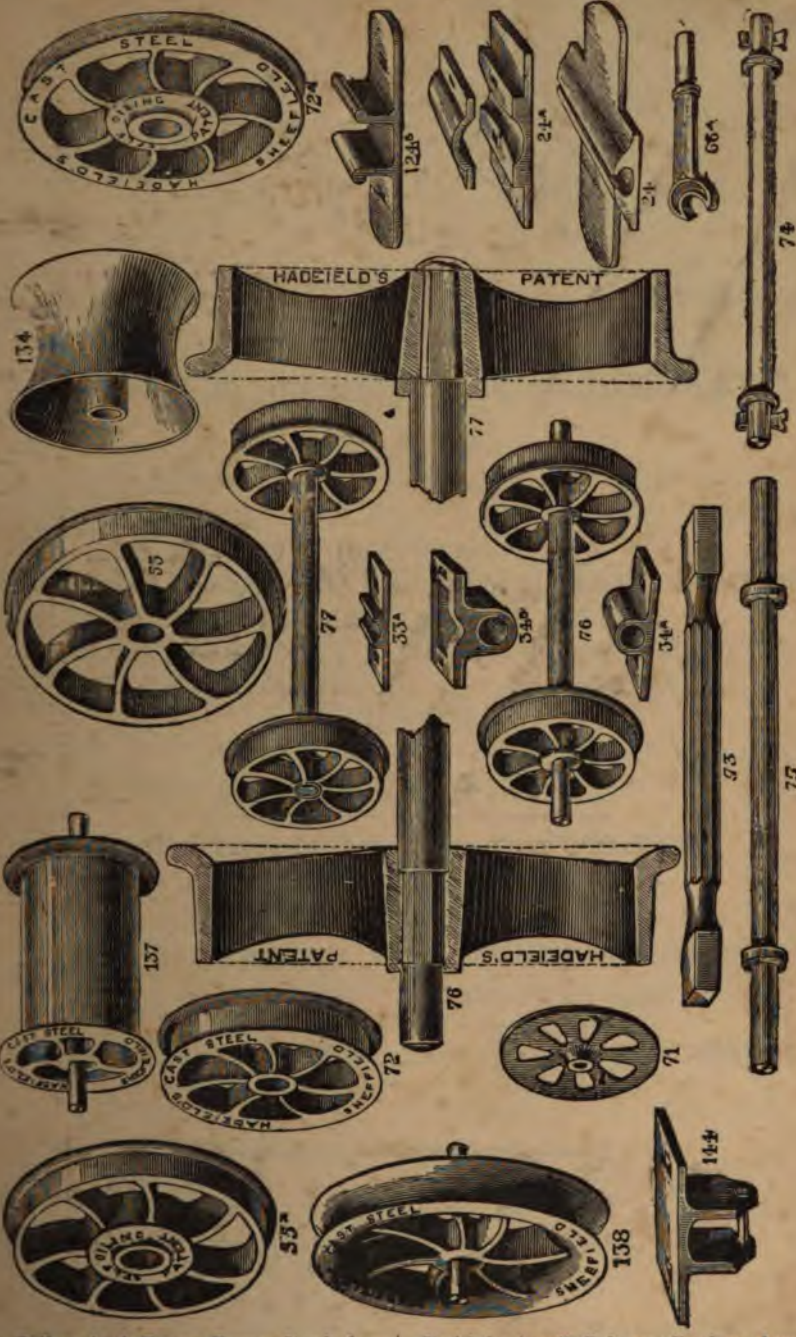
ATTERCLIFFE SHEFFIELD.



REGISTERED TELEGRAPHIC ADDRESS: HADFIELD SHEFFIELD

HADFIELD'S STEEL FOUNDRY Co., SHEFFIELD

Sole Makers of HADFIELD'S Cast Steel Wheels, Rollers, Pulleys, Pedestals,



Rollers, Pulleys, Angle Sheaves, Frames, Stands, &c.—See our lists of over 300 different patterns. They possess great durability, lightness, and strength and add considerably to the life of the steel or other ropes.

Self-oiling Wheels (Patent)—Many thousands now at work. Save at least 50 per cent. of oil or grease. Easily charged once-filled. Reduce friction and wear and tear to a minimum.

Pedestals, Bushes, Cage Guides, Buffer Boxes, Points, Crossings, Wedges, and other Steel Colliery Castings and forgings of every description.

Over 2,000 different patterns of above in stock, ready for use on the shortest notice. New patterns made to suit special requirements free of charge for quantities

Steel Axles, to suit all classes of haulage, of our spe mild and dense quality, standing 38 tons tensile st with 26 per cent. elongation and upwards; many *hundr of thousands* in daily use giving every satisfaction.

Steel Gearing of all kinds. Machine moulded or fr full patterns, also the new Helical Gear Wheels.

Miscellaneous Steel Castings, up to 16,000 lbs. eac replace expensive wrought-iron and steel forgings, heavy iron castings.

NOTE.—Beware of spurious and cheap imitations; we constantly replacing such. See therefore t Hadfield's name is on every wheel.


600025081M

THIRD EDITION of Volume I., Revised and Enlarged, Price 13s. 6d

"The Mechanical Engineering of Collieries."

DEALING WITH

LAYING OUT SURFACE PLANT AT COLLIERIES.
WINDING ENGINES. COLLIERY ROPES AND DRUMS
CAGES AND CONDUCTORS.
THE KŒPE SYSTEM OF WINDING. HEADGEARS AND PULLEYS
BRAKES FOR WINDING AND HAULING
PIT BANKS AND HEAPSTEADS. TIPPING AND SCREENING.
STEAM BOILERS. VENTILATING MACHINES.
THE INDICATOR.
AND A NEW CHAPTER ON WINDING APPLIANCES, PAST, PRESENT AND FUTURE.

With 200 specially prepared Illustrations.

ALSO HISTORY OF

THE WIGAN MINING AND MECHANICAL SCHOOL,

FROM ITS FOUNDATION; WITH ENGRAVING.

LONDON: *Colliery Guardian* OFFICE, 49, ESSEX STREET, STRAND, W.C.

[*In both these volumes all rights are reserved.*]



Sincerely Yours
C. M. Percy.

Engraved by W. J. Aldis.

THE

MECHANICAL ENGINEERING

OF COLLIERIES

BY

C. M. PERCY,

Member of the Institution of Mechanical Engineers, Fellow of the Geological Society, Member of the Mining Institute of Scotland, Lecturer on Engineering at the Wigan Mining and Mechanical School, &c., &c., &c.;

CONSULTING ENGINEER.

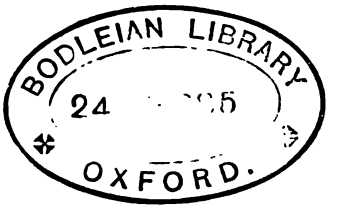
VOLUME II.

LONDON:

"COLLIERY GUARDIAN" OFFICE, 49, ESSEX STREET, STRAND, W.C.

1885.

1864. d. 1.


BODLEIAN LIBRARY
24
OXFORD.

TO

ALFRED HEWLETT, Esq.,

OF

HASELEY MANOR, WARWICK,

THIS WORK IS

DEDICATED

AS A HUMBLE TRIBUTE TO HIS EMINENCE
IN THE MINING WORLD, AND
IN REMEMBRANCE OF TWENTY HAPPY YEARS SPENT
IN HIS EMPLOY,

BY HIS FAITHFUL SERVANT,

THE AUTHOR.

PREFACE.

In offering the Second and concluding Volume of *The Mechanical Engineering of Collieries* to the mining world, there is but little to say. Nearly four years ago, on the encouragement of many friends and at the request of many students, I, with fear and trembling as to the result, but with a determination to do my best, took the work in hand.

The first volume was published two years ago, and the first edition was disposed of in six months. A second edition was issued, and that also has been practically exhausted. The sale has covered every mining district in the United Kingdom, and has extended to the Continent, to America, and the English Colonies.

Indeed, my American friends have published the articles week by week, copying them from the excellent journal under whose auspices I entered the literary world, *The Colliery Guardian*.

These facts, together with another—namely, that for nearly four years which the weekly publication has covered in the chief coal mining paper in the world there has never been one opposing, fault-finding, or unfriendly criticism—have pleased me much. The critics and the public have been generously kind to me.

The volume which I now offer goes over much more ground than its predecessor, and deals with the various subjects more elaborately; and the illustrations are more numerous, and of a higher character.

To have dealt as the matter deserves with *Screening Appliances, the Exhaust Injector, Mechanical Ventilation, Automatic Expansion in Winding Engines, Pumping, Haulage, Steel Castings, Air-compressing Machinery,* and *Useful Memoranda for Mining Engineers,* is far beyond

my powers. But the assistance I have had from friends at home and abroad induces me to hope that my four years' writing, recording a quarter of a century's experience, may not have been in vain.

I express my sincere acknowledgments to all those interested in mining matters in various parts of the world who have been good enough to receive my first volume with an amount of kindness and good-will which I could not have anticipated.

The second volume, I hope, will be received as favourably, not on account of any high literary merit or great learning in its pages, but simply because it is an honest and unambitious effort to place in compact form information which mining authorities and students all over the world will be none the worse for having at their command.

Some exceptions may be taken to the simple style in which the work is written. That is the one merit I claim, that any person at all engaged in mining operations, and possessing even the rudiments of an education, can comprehend all that has been written.

Very many of those on whom we depend for the effective getting of our coal and the safe working of our mines have not received the training of a university graduate, and I have written chiefly for such hardy sons of toil.

Years hence, some abler pens than mine will treat on colliery mechanical appliances; and if I live, their works shall be received by none more heartily than by myself.

Till then, perchance, this humble effort may find a corner on library shelves, and its writer a place in the thoughts of his friends and fellow-workers in the great mining industry all over the world.

C. M. PERCY,
CONSULTING ENGINEER.

King Street, Wigan,
New Year's Day, 1885.

CONTENTS.

CHAPTER I.

APPLIANCES AT ABRAM COLLIERIES AND HAYDOCK'S REVOLVING TABLES.

The Abram Collieries—Seams of Coal worked and Depths—Plant at the Various Pits—Fox and Hopkinson's Corrugated Boiler Flues—Corliss Type of Winding Engine—Weight of Air passing through Mines in Twenty-four Hours—Daily Output of Coals—Horse Power of Engines and Boilers—Manufacture of Coke—Generation of Steam from Waste Heat of Coke Ovens—Ormerod's Safety Links to prevent Accidents by Overwinding—Construction of Pit Banks—Steam Lifts—The Abram Company and Education, Elementary and Technical—Growing Necessity for Picking and Cleaning and Separating Coals—Special Importance at Abram—Mr. William Haydock and his Revolving Tables—Principles and Construction and Advantages of his Appliances—Their Probable Extensive Adoption ... ... pp. 1-9

CHAPTER II.

THE EXHAUST STEAM INJECTOR.

The Injector of M. Giffard—Mr. Stewart's Experiments—Papers by Mr. John Robinson—English Engineers incredulous—Suggested Theories—Mr. Robinson—Sir Frederick Bramwell—Sir William Siemens—Professor Goodeve—The Action of the Injector explained in the word "Concentration"—The Exhaust Steam Injector of Hamer, Metcalfe, and Davies—Experiments made by Mr. Saville—Its Introduction to the Public in 1880—How attached to an Engine and Boiler—How it works—Particulars of two Elaborate Experiments showing Heat gained and Water saved—Its Advantages over other Arrangements of Heating Feed-water—Needs no Attention, and can be applied to all kinds of Non-condensing Engines—Testimonials as to Efficiency from all parts of the Country and from Abroad 10-19

CHAPTER III.

AUTOMATIC EXPANSION GEAR FOR WINDING ENGINES.

Conditions which good Winding Engines should fulfil—Modern Winding Engines not Economical—Extravagance of Non-condensing and Non-expansive Engines—Difficulties in applying Expansion Gear to Winding Engines—The Automatic Expansion Gear of Mr. Arthur J. Stevens—The Object, the Method of Action, and Advantages—The Great Western Colliery, Pontypridd—Diagrams from the Great Western Colliery Engines, with and without Expansion—The Astley and Tyldesley Collieries—Mr. G. H. Peace—Description of Winding Plant—Diagrams from the Engines with and without Expansion—Results at Astley and Tyldesley—Possible Saving at Collieries in the United Kingdom by the Application of Automatic Expansion Gear ... 20-27

CHAPTER IV.

COCKSON'S SILENT GUIBAL VENTILATING FAN.

The Defects of the Ordinary Guibal Fan—Advantages claimed for the Cockson Fan—Comparison with the Schiele—Construction of the Fan—The Alexandra Colliery of the Wigan Coal and Iron Company—Ventilation by Furnace—Ventilation by Fan, and Saving effected—Horse-power and Useful Effect—Speed, Quantity of Air, and Water Gauge—Engines for Working the Fan—Method of Communication between Engine and Fan—Rope Gearing—Proportions of Pulleys—Comparison between Straps and Ropes—The Ventilating Plant at the Alexandra Colliery—Mr. Cockson's Efforts in connection with Ventilation ... 28-32

CHAPTER V.

THE IMPROVED SELF-REGISTERING SIGNAL INDICATOR.

Indicators needed to show to the Engineman the Position of his Cage in the Shaft—Early Appliances—Gradual Improvements introduced—The Indicator attached to Modern Winding Engines—Objections to Bells in connection with Indicators—The Pepper Mill Brass Foundry Company—The Improved Combined Self-registering Signal Indicator—Its Simplicity and Freedom from Springs, and Non-liability to get out of order—The Position of Load is indicated—The Number of Windings is registered—It shows the Number of Signals that have been given—Can be generally applied to any Style of Engine for Winding or Hauling at Collieries, and for Hoists at Blast Furnaces 33-37

CHAPTER VI.

AN ARRANGEMENT OF MECHANICAL SCREENING.

Brooks and Pickup's Collieries, Burnley—Waddell Fan—Bailey's Fan Recorder — Counterbalance Chains — Endless Chains — Fisher's Method of Loading and Unloading Colliery Cages—The Mechanical Engineers in Belgium—The Mariemont Collieries — M. Guinotte — Automatic Machinery for Hauling, Emptying and Classifying Coal, Loading it on Trucks, and for Cleaning—M. Briart—Results of Hand Screening and Mechanical Screening Compared—Mr. Landless—His Mechanical Screen at Burnley—Defects of all Fixed Screens—Construction of the Burnley Screen—Method of Working—Amount of Coals that can be dealt with—Effective Separation of Round and Small, and Freedom from Breakage—The Arrangements at Mariemont, in Belgium, evidently copied from the Landless Screen at Burnley 38-46

CHAPTER VII.

PUMPING ENGINES AND APPLIANCES.

Introductory.

Comparison between Pumping and Winding Water—Arrangements when Water is wound—Tank swung below the Cage—Teeming Appliances—Pumping Engines should be equal to Double the Probable Work—Lodge Room should be provided—Pumping Engines on the Surface and Underground—Height and Number of Lifts—Height of Suction—The Siphon, its Use—Effective and Defective Construction of Siphon—The Principle of the Siphon—Conditions under which a Siphon will and will not act—Illustrations of the Application of the Siphon and of the Inertia of Water in Pipes—Theoretic Velocity from a Siphon 47-57

CHAPTER VIII.

PUMPING ENGINES AND APPLIANCES.—HERO TO SAVERY.

The Early History of the Steam Engine—The Pneumatics of Hero—Mr. Bennett Woodcroft—Vice-Chancellor Greenwood—Knowledge of Expansion of Steam, the Slide Valve, the Clack, the Metallic Piston and Metallic Cylinder before the Christian Era—Fire Engines—The Ancient Theory of a Vacuum and that Water under the Action of Fire was transformed into Air—Porta—Branca—Solomon de Caux's Appliance for producing a Fountain by the direct force of Steam—The Marquis of Worcester; his *Century of Inventions* and his Water-commanding Engine — What Lord Worcester

actually accomplished—Sir Samuel Moreland, Master of Mechanics to the King of England—Dr. Papin, his Boiler Safety Valve, and his Engine Piston—Captain Savery and the "Miners' Friend"—England's Need of Pumping Engines 58-69

CHAPTER IX.

PUMPING ENGINES AND APPLIANCES.—SAVERY TO WATT.

The Correct Theory of the Vacuum—The Ancient Idea that Nature abhorred a Vacuum—Galileo—His Answer that Nature's Abhorrence of a Vacuum was Limited—The inoperative Pump in the Duke of Tuscany's Garden—Torricelli and his Researches and Experiments—Invention of the Barometer and Discovery of the real principle of Atmospheric Pressure—Savery's Engine—Newcomen's Improvements—Application of the Piston and the Beam and the Jet Condenser—Action of Newcomen's Engine and its Advance on all its Predecessors—Automatic Valve Gear—The Anecdote of the idle Lad—Working Results of Newcomen's Engine—Leupold—Blakey—Beighton—Smeaton ... 70-80

CHAPTER X.

PUMPING ENGINES AND APPLIANCES. JAMES WATT.

Watt and Stephenson—The Stationary Engine a greater Invention than the Locomotive—Watt did invent the Stationary Engine in all its essential Principles—Stephenson did not invent the Locomotive nor any of its essential Principles—Defects of Newcomen's Pumping Engine—Limited in Power, and extravagant in Working—Watt's brilliant series of Inventions—The Separate Condenser—The Cylinder Cover and Gland and Stuffing Box—Steam Expansive and Double-acting Engines—Parallel Motion—Crank and Connecting Rod—Sun-and-Planet Wheels—The Governor and Throttle-valve—The Steam Jacket—The Indicator—The Dead Plate—The Counter—The Pressure Gauge—Consumption of Coal per Horse-power with Newcomen and with Watt—Investigations as to Latent and Sensible Heat of Steam—Improvements in Pistons—Pride in his Parallel Motion—Single-acting and Double-acting Engines—The Steam Jacket and Advantages claimed for it—How Steam may be used in the Cylinder—Non-condensing and Non-expansive—Condensing and Non-expansive—Non-condensing and Expansive—Condensing and Expansive—The Advantages of Condensing and Expansive Engines ... 81-94

CHAPTER XI.

PUMPING ENGINES AND APPLIANCES.—CORNISH PUMPING ENGINES AND PITWORK.

Engineering in Cornwall—The Cornish Boiler—The Lancashire Boiler—General Principles of Watt's Pumping Engine, Single-acting—William Howe, of Clay Cross—The Pumping Engine at Clay Cross—Cornish Pumping Engines without Circular Motion compared with the Fly-wheel Pumping Engine—Rule to ascertain the Quantity of Water required for Condensation—Table of total Heat of Steam—Pressure in pounds per Square Inch, and Volume compared with Water—The Cornish Bull Engine—Its Advantages over the ordinary Single-acting Cornish Engine—The supposed High Duty from Pumping Engines in Cornwall—Lean's *Reporter*—How Expansion is effected in Cornish Engines—Pumping Engines at Waterworks—Speed of Pumping Engines—Cornish Engine at the Astley and Tyldesley Collieries—Advantages of having the Beam below the Engine—Specification of a Double-acting Upright Condensing Pumping Engine on the Cornish Principle 95-113

CHAPTER XII.

PUMPING ENGINES AND APPLIANCES.—PIT WORK OF PUMPS.

Shaft Arrangements of a Plunger Lift—Foundations of Stone and of Timber—Lift resting upon Iron or Timber Horse-trees—Transverse Strength of Timber—Built-up Beams—Ram and Chamber—Clacks and Boxes—Arrangements for packing the Ram and examining the Clacks—Points at which Main and Ordinary Horse-trees should be placed—How Horse-trees are secured in the Pit Shaft, and how Pump Stocks are secured—Table of Strengths of Pipes—Allowance for Wear and Tear and Outward Pressure—Eccentricity of Pipes in Cross Section—Structure of a Pump Stock—Joints of Pump Stocks, how made, and how renewed—Pump Rods, their length and how secured to Plunger—Strength of Pump Rods, and Arrangements of Iron Plates at the Joints—How the Movement of the Rods is guided—Rubbing Boards and Banging Pieces—Pump Clacks, how constructed—The Butterfly Clack—The Single-beat or Mitre Valve—The India-rubber Disc Valve—The Cornish Double-beat Valve—The Advantages of the Cornish Valve, and how it becomes an Equilibrium Valve—Pyramid Valves—Requirements of an efficient Pump Valve—Running Lift when sinking—Bucket Pumps, Sliding Piece and Windbore—The Boot Leg—Pump Rods working within the Stocks—Injurious Action of Joint Bolts on Interior

of Stocks—Cases in which a Bucket Pump is advantageous—Pumping Arrangements with the "L" Leg—Difficulties in keeping the Bucket tight—The Height at which the Ram or Bucket should be placed above the Water—Why Water follows the Ram or Bucket—Accidents with Pump Rods and Pumping Cranks—How to have a firm Foundation for the "L" Leg—Pumping Engines with Spur Gearing—Division of a long column into several Lifts, each having a separate Bucket—How the Water Supply for each is regulated—Indicators to show upon the Surface the Level of the Water below 114-127

CHAPTER XIII.

PUMPING ENGINES AND APPLIANCES.—THE COMPOUND DIFFERENTIAL PUMPING ENGINE.

Mr. Henry Davey, of Leeds—His Efforts to improve Pumping Machinery—Economy in Fuel, in Maintenance, and in Construction—Condensation and Expansion—Double-acting Engines working at a High Speed—Inexpensive Foundations—Defects of the Cornish Pumping Engine—Varying Strain—Irregular Speed—The Differential Valve Gear—Distribution of Steam proportionate to Load—Reverses the Steam when Load is suddenly lost—The Gear is automatic, and the Shocks inevitable with Cornish Engines avoided—Description of the Compound Differential Engine, and Action of its Mechanism—Experiments at Lambton Colliery—Application of the Engine at Waterworks—Figures illustrative of the Differential Gear—Beginning of Stroke—Light Load, early Cut-off—Heavy Load, late Cut-off—End of Engine Stroke—The Compound Differential Engine and the Cornish Engine compared—Expansion in the Cornish Engine—Expansion in the Compound Engine—Application of the Differential Gear to other Engines—Compound Differential Engine underground in South Wales and at Staveley Collieries—The Science and Art Department, South Kensington, and Davey's Compound Engine—Good Results with the Engine above ground and below ... 128-139

CHAPTER XIV.

PUMPING ENGINES AND APPLIANCES.—PUMPING ENGINES PLACED UNDERGROUND.

Advantages of Surface Pumping Engines—Running Lifts whilst Sinking—Winding Water—Steam Pumps; their Advantages—Most Favourable Conditions under which such Engines can be applied—Causes of weakness in Pipes—How to avoid them—Vertical and Horizontal Casting—American plan of Cooling Castings—Horizontal Fly Wheel Pumping Engines working in

Pairs—Conveyance of Steam from Surface—Loss of Pressure—Different Systems of Transmitting Power to Underground Pumping Engines—Steam Engines and Steam Boilers Below—Steam Engines Below and Steam Boilers Above—Air Compressing Engines Above and Pumping Engines Below—Hydraulic Power—Ropes or Chains and Pulleys—Securing Pipes in Shaft—Allowance for Expansion in Steam Pipes—Defective Expansion Joint—Effective Expansion Joints—Dealing with Exhaust from Pumping Engines — Pipe Condenser — Holman's Condenser — Experiments at Norley Collieries—Experiments at Lamb and Moore's Collieries —Hayward Tyler's Condenser—The Blow-through Valve—Speed and Efficiency of Underground Pumping Engines—Examples and Rules as to Power of Underground Pumping Engines 140-153

CHAPTER XV.

PUMPING ENGINES AND APPLIANCES.—PUMPING ENGINES PLACED UNDERGROUND.

Messrs. Joseph Evans and Sons, of Wolverhampton—The Cornish Steam Pump—Its special Advantages—The Patent Rotating Disc Valve—Importance of good Valve Arrangements in Pumps —Quick Opening and Closing without undue Concussion—Sufficiency of Opening—Suction Air Vessels—The Cornish Double Ram Steam Pumping Engine for moderate or high Lifts—Plungers most effective for great Pressures or for dirty Water—Valves with India-rubbers or Springs at the Back to ensure quick Closing—The Cornish Direct-acting Steam Pump for moderate Lifts—Pump Piston or Bucket—Cornish Pumps popular on account of Cheapness and Simplicity and small Space required—They are not Economical—The Horizontal Double-acting Ram Pumping Engine with Fly-wheel—Its Advantages—The Vertical Fly-wheel Ram Steam Pump—The Horizontal Cornish Compound Condensing Pumping Engine—Specification of Pump to raise 20,000 gallons an hour 450 feet high with 35 pounds of Steam—Hydraulic Pumping Engine for Mines—Circumstances under which Hydraulic Power is effective—Underground Pumping Engine worked by Endless Rope and Clip Pulley—Pumps at Hargreaves' Collieries, Burnley, worked by Endless Chain—Testimonial to Messrs. Joseph Evans and Sons from Amsterdam 154-164

CHAPTER XVI.

PUMPING ENGINES AND APPLIANCES.—DAVEY'S HYDRAULIC MACHINERY.

Hydraulic Engines pumping Water out of Dip Workings to Sump —Head of Water from the Surface enabling the Pump to empty the Dip Workings and its own Power Water into the Sump—

Description of the Arrangement—Speed of Pump and Useful Effect—Arrangement for increasing or decreasing the Size of Pumps—Hydraulic Engines for pumping Brine from a deep Salt Mine—Head obtained by Accumulator placed at the Surface—Useful Effect—Special Application of Hydraulic Pump—Arrangement in which the same Pipe serves for the Driving Column and the Delivery Pipe—Air Vessels—Wipperman and Lewis's Automatic Pump for Supplying Air Vessels with Air—General Remarks on Pumping Engines and Appliances—Storage to be provided—Pumps should be equal to Double their Work—Position of Pumping Engine and Type of Engine to be used—The best Kind of Pumping Engine for the Surface is the Cornish or Compound Differential—The best for Underground Pumping is the Horizontal Double-Acting Long Stroke Ram Pumping Engine with Fly Wheel 165-173

CHAPTER XVII.

MINING MACHINERY AT WHITEHAVEN IN 1806.

Mr. John Henry Harden, of Phœnixville, Pennsylvania—Mr. John B. Longmere, of Whitehaven—William, Lord Lowther—Scalegill New Collieries—Particulars of Borings—Steam Engines—William Pit Rotative Machine—Description and Illustrations of the various Parts—William Pit Temporary Pumping Engine—Description and Illustrations of the several Parts—How Steam is generated in the Boiler—How the Engine is started and how it Works—Description of an Atmospheric Engine—A Double-powered Atmospheric Engine with two Cylinders—Particulars of the Winding Appliances—Depth of Pit and Period of a Winding—Load Raised—Probable Power of Winding Engine—Comparison between the Whitehaven Engine and Modern Winding Engines—Probable Power of Pumping Engine—Size of Pump, Height of Lift, and quantity of Water 174-183

CHAPTER XVIII.

MEMORANDA FOR MINING ENGINEERS.

Actual and Theoretic Efficiency of Coal—Duty of an Engine—Nominal Horse-power — Useful Horse-power — Indicated or Actual Horse-power—Table of Approximate Horse-power with Cylinders 6 in. to 60 in. diameter—Average Effective Pressure 30 lbs. and Average Piston Speed 250 feet per minute—What is Average Effective Pressure?—Rule to find Diameter of Winding Drum and Pressure of Steam, knowing the Load, the time of Winding, and Diameter of Cylinder—Different Kinds of Steam, Saturated, Wet and Superheated—Table of Saturated Steam, showing Absolute Pressure, Latent Heat, Sensible Heat, Boiling Point, and

Volume compared with Water—Rule to find Quantity of Condensing Water required—Strength of Materials—Tenacities—Resistance to Compression—Strength to resist Twisting Strains—Transverse Strengths—Dead Load and Live Load—Conductivity of Metals—Temperature of Fusion—Specific Heat—Expansion produced by Heat—Moduli of Elasticity—Pressure from the Barometer, showing Height of Mercury Column in Inches, Pounds Pressure per Square Inch and per Square Foot—Fahrenheit's and Centigrade Thermometers—Pressure of Water Columns—Head, Velocity, and Quantity of Water from Pipes, showing Diameter of Pipe in Inches, Head required per 100 feet and Gallons delivered per minute—Delivery of Water in Pipes—To find the Quantity of Water in a Pipe—To find the Quantity of Water delivered by a Pump per minute—Falling Bodies—Weight of Pipes, &c.—Effect of Temperature upon Iron and Copper—Weight of a Boiler—Collapsing Pressure of Boiler Tubes—Weight of Cubic Inch of Wrought Iron and Cast Iron—Fixing the Number of Boilers required for the Generation of Steam—Determining the Minimum and Maximum Diameters of a Perfect Compensating Drum—Mechanical Ventilation—Work in Velocity of Air apart from Friction—Water Gauge calculated from Circumferential Velocity of Fan 184-205

CHAPTER XIX.

HAULAGE.

Introductory.

Importance of Hauling Machinery at Modern Collieries—Mr. Greenwell's Treatise on Mine Engineering—Hauling Arrangements in Early Times—The Basket on the Back—The Wheelbarrow—The Sledge, or Sled—Corves and Rolleys—Coal Tubs—Dr. Le Neve Foster in the *Encyclopædia Britannica*—Carriage of Blocks in the State Mines of the Ardennes—Iron Ore in Wooden Trays in the Forest of Dean—The German Hund—Cast-iron Tram Plates—Iron and Steel Rails—Cost of Haulage of Coals a Century ago compared with Modern Times—The Tail Rope Committee of the North of England Institute—W. Cochrane—G. B. Forster—John Daglish—Lindsay Wood—R. F. Matthews—Belgian Engineers—MM. Briart and Weiler—The Mariemont Collieries—Report on Haulage by Emerson Bainbridge—Lectures on Mining by M. Callon, French Inspector-General of Mines—Translation by W. Galloway and Dr. Le Neve Foster—Different Systems of Haulage in Different Districts—General Principles of all Hauling Arrangements—Machinery should always be used in preference to Horse or Manual Labour—Haulage Arrangements should communicate between Working Places and Pit Bottom—Machinery should have Power in Excess of Work—Haulage Power of Various Kinds—Water applied to Turbines and Hydraulic Engines—Electricity

a Possible Power in the Future—Methods of Transmitting Power now most General—Steam in Engines placed Above Ground—Steam generated Above Ground working Engines placed Underground—Steam generated Underground and driving Engines there—Compressed Air—Arrangements when Roads have Falling Gradient to Pit Bottom—Systems of Haulage—Direct Haulage—Tail Rope Haulage—Endless Rope under the Tubs—Endless Rope over the Tubs—Endless Chain 206-213

CHAPTER XX.

HAULAGE.—THE DIRECT SYSTEM.

Character of Roads—Construction of Tubs—Fast and Loose Wheels—Coning of Wheels—Friction of Wheel upon Rail and of Axle in its Bearing—What is Friction? Where Useful and where Injurious? The Laws of Friction—Co-efficient of Friction—Examples showing how Friction may be Increased or Decreased—The usual Co-efficient for Ordinary Colliery Tubs—Self-acting Haulage Arrangements—Jig Wheels and Jig Drums—Brakes for Jig Arrangements—Meaning of the Direct System of Haulage—Gradient to allow Empties to Run Back—Hauling Engines——Advantages of Horizontal Hauling Engines—Defects of Vertical Hauling Engines—Speed of Pistons in Intermittent and in Continuous Haulage—Hauling Engines working off First Motion—Hauling Engines with Spur Gearing—Example showing Size of Engines required to do certain Work—Example showing the Amount of Work certain Engines are capable of—Appliances to keep Hauling Ropes off the Floor—Rollers and Pulleys—Injury to Rope working on Floor or on Non-revolving Pulleys—Arrangement of Roller Pulley in Frame—Pulleys hung from Roof-Guide Pulleys—Arrangements for Rope passing round Curves—Changing the Direction of Hauling Rope—Endless Ropes of Self-acting Inclines—Tubs upon Heavy Gradients—Appliances for Holding the Gang when Rope breaks—Difference of Breakage with Descending Gang as compared with Ascending Gang—Importance of High-class Materials in Ropes and Chains and Drawbars and Cappings—M. Callon's Lectures on Mining—What is a Safe Load for Ropes and Chains? The Materials of which Chains and Ropes are made should be Tested—Ropes and Chains should never be Over-worked 214-232

CHAPTER XXI.

HAULAGE.—THE TAIL ROPE SYSTEM.

What is the Arrangement known as Tail Rope?—Its Importance and Popularity in the Northern Coalfields—The North of England Institute—The Report—G. H. Wright—Emerson Bainbridge

—G. C. Greenwell—Mr. Berkeley—Tail Rope Haulage at the Marley Hill Colliery in County Durham—Advantages and Disadvantages of Hauling Engines under the Roadway—Length of Rope in Tail Rope Haulage—Rollers and Pulleys for supporting the Hauling Rope—Bringing Loaded Tubs out from various Stations—Useful Effect at Marley Hill Colliery—Mr. Greenwell's Co-efficients of Friction—Speed of Marley Hill Haulage—Loss of Steam Pressure in Travelling through 200 Yards of Pipes—Cost of Conveyance of Coals—Advantages of Steam Receivers—Advantages of Receivers when working with Compressed Air—Comparison in Cost as between Horse and Mechanical Power for Haulage—The Tail Rope Arrangement in its Simplest Form—Results of Reading and Discussing Mr. Greenwell's Paper—High Appreciation of North of England Haulage Report—The North Hetton Colliery—Nicholas Wood—George Stephenson—Haulage Arrangements at Hetton—High Speed—Arrangements at Seaham—Description of Engines and Boilers—Indicator Experiments—Arrangements at Seaton Delaval—Low Useful Effect—Probable Defective Arrangements for the Ropes—Arrangements at Harradon Colliery—Description of Engines and Boilers—Indicator Experiments—Useful Effect—Murton Colliery—Special Arrangement of Friction Wheels for working a Pump—Advantages of the Appliance—Indicator Experiments—High Useful Effect and Low Expenditure of Power on the Engines—Experiments to find Friction of Tubs—Cost of Leading Coals at Murton, and Harradon, and Seaton Delaval, and at Seaham—Summary of North of England Report—Leading Features of Tail Rope Haulage—Disadvantages of the Tail Rope System—Usual Appliances—Loose Running Drums—Curves can be worked on the Tail Rope System—Methods of attaching Branch Ends to Main Rope—Methods of taking Rope round Curves—Connection between Rope and Set of Tubs 233—249

CHAPTER XXII.

HAULAGE.—THE ENDLESS CHAIN SYSTEM.

No one System of Haulage generally adaptable—The Endless Chain eminently suitable at Burnley—Used for Surface and Underground Haulage—The Endless Chain automatically attaches to the Tubs—Receives comparatively no Injury by Exposure to Weather—Arrangements at Rowley Colliery—Endless Chain for Winding—Disadvantages of the System—Haulage Chain passing from Surface to Underground—Limit to the Effectiveness of the Arrangement—Impracticability with Pits of considerable Depth—Engines and Boilers below Ground—Description of Engine—Connection of Boilers with Upcast Shaft—Advantages and Dangers of Boilers placed Underground—How Power is transmitted from Engines to Chains—Number of Hauling Chains—Appliances for throwing any Chain in or out of Gear—Defectiveness of ordinary

Forms of Clutch Gear—Construction of Driving Pulleys—Object of the "Feet" placed upon the Pulleys—Guide Pulleys—Obtaining needful Friction for the Driving Chains—Weight and Safe Load of Chains—Stretching of Chains—Cause of Wear in Chains and how prevented—Position of Tubs—How Branch Chains are worked—Chains working upon Level Roads—Chains working to the Dip—Chains working to the Rise—Construction of Tubs at Burnley—Attachment of Chain to Tubs—Speed of Endless Chains—The Hargreaves Collieries at Burnley—Mr. R. Handsley—Mr. H. Waddington—Length of Endless Chain in Use—The North of England Committee on Endless Chain Haulage—Economy as regards Roads—Self-acting Curve in Endless Chain Haulage—Hapton Valley Colliery—Description of Gearing and Arrangement of Tubs—Experiments as to Power—Cost of leading—Gannow Colliery—Description of Gearing—Cost of leading—Rowley Colliery—Cost of leading—Surface Endless Chain at Burnley—Cost of leading—Surface Endless Chain at Clifton Hall—Absence of Forks from Tubs—Disadvantages of the Arrangement—The South Wales Endless Chain—Haulage by Endless Chain at Coltness—Description of Engines and Gearing and Roadway—The Work upon the Engines—Experiments with Dynamometer—Size and Weight and Strength of Chain—Mishaps in Working—Arrangements for stopping the Tubs when Chain breaks—Excellence of the Coltness Appliances—Mr. R. Russell—Endless Chain in the North of England—Arrangements for passing round Curves 250—265

CHAPTER XXIII.

HAULAGE.—THE ENDLESS ROPE SYSTEM.

Advantages of Haulage by Endless Rope—Saving in Weight as compared with Endless Chain—Chains more frequently break than Ropes—Cases where Chains have an Advantage—Chains will work even on Defective Machinery—Ropes require good Appliances—The Endless Rope over the Tubs at Brinsop Hall Colliery, Wigan—The Endless Rope under the Tubs at Clifton Collieries, Nottingham—Power to work Endless Rope Haulage—The Best Arrangement is Engines above Ground and Ropes in Shaft—Advantages and Disadvantages of the Arrangement—Example for a Pit 700 yards Deep—The North of England Report—No. 1 and No. 2 Systems. Appliances for tightening and giving needful Friction—Method of attaching Tubs to Rope—Haulage at Shireoaks—Size of Engines—Amount of Work—Description of the Friction Driving Gear—Speed of Rope—The Useful Horse Power—The Cost of Haulage—California Colliery, Wigan—Tightening Arrangements and Driving Gear—Speed o Rope—Newsham Colliery—Attachment of Tubs to Rope—Clip Pulley—Speed of Rope—Cost of Haulage—Cinder Hill Colliery—

Speed of Rope—Arrangement to give needful Friction for Driving—Method of Attaching Tubs—Conveyance round Curves—Cost of Haulage—Bridge Pit—Description of Engines and Boilers—Amount of Work done—Appliances to give Friction and obtain Tightening—Transmission of power to work Branch Roads—The Speed of Rope—Methods of Working Curves—Cost of Haulage—Scot Lane Collieries, Blackrod—Peculiar Method of Attachment—Difficulties on Light or Irregular Gradients—Mesnes Colliery, Wigan—Engines on the Surface—Tightening Appliances at Bottom of Shaft ... ... 266—274

CHAPTER XXIV.

HAULAGE.—THE ENDLESS ROPE SYSTEM AT BRINSOP COLLIERIES.

The Brinsop Hall Collieries, Wigan—Mr. A. H. Leech—Mr. W. Holding, of Cossall Collieries, Nottingham—Messrs. John Wood and Co., Engineers, Water Heyes Foundry, Wigan—Description of the Brinsop Haulage—Tightening Appliances in the Mine—Method of working Branch Roads—Amount of Work done—Cost of Haulage—Life of Ropes—Extravagance of Compressed Air—Specification of a Pair of Horizontal High Pressure Hauling Engines—Steam Cylinders—Pistons and Rods—Cross-heads—Slide Bars and Blocks—Connecting Rods—Cranks—Crank Shaft and Pedestals—Fly-wheel—Valve Motion—Foundation Plates—Gearing and C Pulleys—Defectiveness of C Pulleys—Proposed Amendment—Advantages of Grooved Pulleys—Haulage Arrangements at Rainford Collieries—Mr. T. Y. Greener—Self-contained Hauling Engines—John Wood and Co.'s Experience in Colliery Machinery—Freedom from Mishaps with Ropes at Brinsop—Careful Inspection—Speed of Hauling Ropes—Method of attaching Tubs—Advantages of the Chain over the Fork... 275—284

CHAPTER XXV.

HAULAGE.—THE ENDLESS ROPE SYSTEM AT CLIFTON COLLIERY, NOTTINGHAM.

Ropes working under the Tubs—Mr. Henry Fisher—Paper before the Chesterfield and Derbyshire Institute of Engineers—Comparison between the Slow-working Endless Rope and (first) the Endless Chain, (second) the Tail Rope, (third) the Quick-running Endless Rope—Different kinds of Driving Wheels—The Clip Wheel—The Ordinary C Pulley—Pair of Grooved Wheels—Disadvantages of Clip Wheels—Grooved Driving Wheels are the best—Improvement in form of C Wheels—Lining of Cast Steel—Attachment of Tubs to Rope—Special Requirements—Fisher's

Patent Clip Hook—Details of Construction—Guide Pulleys for enabling Tubs to pass round Curves—Hauling Engines at Clifton —Speed of Rope—Fisher's Friction Clutch—Details of Construction and Principle of Action—Its general Applicability to all Machinery that has to be thrown in and out of gear—Its special Advantages — Concluding Remarks on Haulage — What is the best System of Haulage?—Mr. C. E. Rhodes, of Car House Collieries, Rotherham—The Aldwarke Main Collieries—Forged Steel Wheels for Colliery Tubs by Mr. W. Eyre, of John Brown and Co.—Construction and Advantages of the Wheels 285—293

CHAPTER XXVI.

HAULAGE.—COMPOUND HAULING ENGINES.

Variety in Hauling Engines—Horizontal or Vertical—Single or Coupled—Geared or on First Motion—Similarity as regards being Non-condensing and working at Moderate Pressures — The System of Haulage largely determines the Class of Engine—For Quick Haulage the Engines should always be in Pairs—For Slow Haulage a Single Engine will answer—Piston Speed for Continuous Working Hauling Engines—Piston Speed in Intermittent Haulage—For Slow Haulage the Engine should be Geared—For Quick Haulage Engines on First Motion are best — Hauling Engines may work (1) Non-condensing and Non-expansive, (2) Non-condensing and Expansive, (3) Condensing and Non-expansive, (4) Condensing and Expansive—The usual Hauling Engine is Non-condensing and Non-expansive—Surface Engines might be Condensing and Expansive — Difficulty as to Condensing Arrangements underground — Extravagance of Non-condensing and Non-expansive Engines—Example to show that Expansion is Gain—In Theory there is no Limit to Gain from Expansion—In Practice there is a Limit—Why we have so little Expansion in the ordinary Haulage Engines — Machinery for the Intercolonial Coal-mining Company of Nova Scotia and Montreal—A Compound Hauling Engine—High Initial Pressure and High Ratio of Expansion—Walker Brothers, Engineers, of Pagefield Ironworks, Wigan—Specification of Engines—Cylinders and Pistons and Rods—Cross Heads—Motion Bars—Connecting Rods—Cranks—Eccentrics, and Rods, and Straps, and Reversing Links, Drums, Bearings, Framing, Friction Gear—Defects of usual Clutch Gear—Friction Gear of Mr. Henry Fisher, of Clifton Collieries, Nottingham—Joy's Valve Gear—Disadvantages of Eccentrics and Links—Advantages of Joy's Valve Gear —Sir William Siemens—Description of Joy's Gear—Compounding — What is a Compound Engine? — Two-Cylinder, Three-Cylinder, and Four-Cylinder Engines — Daniel Adamson— Expansion in Simple and Compound Engines — Advantages of Expansion in Compound Engines — Rule to Proportion the

Cylinders of Compound Engines—The Receiver in Compound Engines—Its Object and Position—Advantages of a Large Receiver—Calculation as to Power of Compound Hauling Engine ... ... 294—307

CHAPTER XXVII.

HADFIELD'S STEEL CASTINGS FOR COLLIERY USE.

Cast Steel for Hauling and other Appliances—The Age of Bronze—The Age of Iron—The Age of Steel—Sheffield the Monarch of the Steel Industry—Armour Plates and Needles—Locomotives and Penknives—Wheels, Axles, Pedestals, Pulleys, and Rollers—Importance of Durability in Colliery Materials—Cast Iron is Treacherous—Requires Constant Renewal—Cast Steel almost Everlasting—Mr. Robert Hadfield, of the Hadfield's Steel Foundry Company, Sheffield—Popularity of the Hadfield Specialties all over the World—Description of the Hadfield Works—Toughness, Durability, Density, and Soundness essential Qualities of Good Steel Castings—Careful Analyses and Elaborate Mechanical Tests—High Temperature of Molten Steel—Difficulties of Casting—Allowance for Contraction—Annealing and Cleaning—Great Variety in Steel Castings—Weights from Several Pounds to Many Tons—Immense Collection of Patterns—Machinery for Finishing the more Elaborate Castings—Tub Wheels Fast upon the Axles—Importance of being made Secure—Hadfield's Method of Fastening Wheels fixed on by Hydraulic Pressure—Tub Wheels Loose upon their Axles—Importance of Efficient Oiling—Hadfield's Self-oiling Wheel arranged for Inside or Outside Bearings—The Advantages claimed for it—Injurious Effects of Bad Rollers and Pulleys upon Hauling Ropes—Advantages of the Steel Pulleys and Rollers—The Self-oiling Roller Boxes—The Registered Angle Pulley and Frame for taking Ropes round Curves—Steel Castings at Blast Furnaces—Hadfield's Patent Manganese Steel—Hard, Tough, and Non-magnetic—Benjamin Huntsman and the Early Days of Steel—Robert Hadfield and Steel Castings—Useful Memoranda for Steel-users 308—320

CHAPTER XXVIII.

AIR-COMPRESSING MACHINERY.

Variety in Types of Air-compressing Machinery—Divided Opinion as to its Use—There are Operations for which it is Specially Adapted—Comparisons as against Hydraulic Power and Steam—Advantages of Compressed Air—Underground Locomotives—General Description of a Modern Air-compressing Engine—Its Action—Maximum Theoretic Effect of Air-compressing Engines

—Average Results in Practice—Cost of the Machinery—Why is the Useful Effect so Low?—Loss of Power by Liberation of Heat—Loss of Power by Liberated Heat Expanding the Compressed Air in the Cylinder—Loss by Limit of Expansion—Proposals to Prevent these Losses—Mr. E. A. Cowper—Sir William Siemens—These Proposals have not been carried out in Colliery Machinery—Early Air-compressing Machines—Experiments in Scotland—Description of the Engine—Valves of Brass and of Gutta Percha—Air-compressing Machinery in Wales—Liberation of Heat during Compression—Formation of Ice during Expansion—Power for Coal-cutting and Tunnelling and Rock-boring Machines—Defectiveness of Air-compressing Engine having no Circular Motion—Colliery Proprietors and Inventors—A Good Coal-cutter still Wanted—Mr. William Daniel, and Messrs. John Fowler and Co., Leeds—Their Air-compressing Machinery in South Wales—Description of the Engines—The Inlet and Outlet Valves—Speed of the Pistons—Water Jackets and Air-Receiver—Construction of Exhaust Passages to prevent Formation of Ice—Experiments to show Useful Effect at Various Pressures—Importance of Indicating the Air Cylinder—Mr. Firth—Mr. C. Cochrane—Mr. E. A. Cowper—Sir Frederick Bramwell's Comparison between Compressed Air and Water Power—Mr. John J. Geach, of Bristol—Mechanical Appliances at the Severn Tunnel Railway—Description of the Air-compressing Engines—Herr Wendelstein, of Lucerne, and the St. Gothard Tunnel—Description of the Air-compressors and the Turbines that worked them—The Sturgeon High-speed Air-compressor—Description of the Engine—Peculiarity in Action of the Inlet Valves—Arrangement for Regulating the Speed—Defects of an ordinary Single Air-Compressor—Importance of Effective Valves—Sufficient Area—Ease and Quickness of Action—Messrs. Walker Brothers, Pagefield, Wigan—Their Excellence in Air-compressing Machinery—Clearance in Air-cylinders—The Air-receiver—Its Twofold Advantage—Mr. D. K. Clark's Manual for Engineers—Experiments on the Resistance of Air through Long Pipes—Loss of Pressure and Leakage of Air at the Mont Cenis Tunnel—The Efficiency of Air-compressing Engines—Efficiency less for High Pressures—M. Pickard on the Efficiency of Compressed Air—Effect of Moisture on Air—Conclusion ... ... 322—350

LIST OF ILLUSTRATIONS.

Figures illustrating Chapter I.

APPLIANCES AT ABRAM COLLIERIES AND HAYDOCK'S REVOLVING TABLES.

1. Corliss Winding Engine at the Abram Colliery.
2. Showing Haydock's Revolving Table in Section.
3. Showing Revolving Table and Fixed Scrapers.
4. Showing Two Screens supplying Coals to Revolving Tables.
5. Showing Two Shoots taking Coals from Revolving Tables into Wagons.

Figures illustrating Chapter II.

THE EXHAUST STEAM INJECTOR.

6, 7, 8, 9, 10, 11. Showing Parts and Applications of the Exhaust Steam Injector.

Figures illustrating Chapter III.

AUTOMATIC EXPANSION GEAR FOR WINDING ENGINES.

12. Stevens' Automatic Expansion Valve Gear.
13. Diagram from Great Western Colliery Winding Engines—Expansion Gear not in Action.
14. Diagram from Great Western Colliery Winding Engines—Expansion Gear in Action.
15. Astley and Tyldesley Colliery Winding Engines with Automatic Expansion Gear attached.

16. Diagram from Astley and Tyldesley Colliery Winding Engines —Expansion Gear not in Action.
17. Diagram from Astley and Tyldesley Colliery Winding Engines —Expansion Gear in Action.

Figures illustrating Chapter IV.

COCKSON'S SILENT GUIBAL VENTILATING FAN.

18. Fan with Iron Casing.
19. Fan Driven with Rope Gearing.
20. Fan Pit used for Ventilation only.

Figures illustrating Chapter V.

THE IMPROVED SELF-REGISTERING SIGNAL INDICATOR.

21. Improved Combined Colliery Self-registering Signal Indicator

Figures illustrating Chapter VI.

AN ARRANGEMENT OF MECHANICAL SCREENING

22. Side Elevation of Upper Portion of Mechanical Screen, showing the Movable Bars and Arrangement of Gearing to Work them.
23. Longitudinal Section showing Fixed and Movable Portions of Screens.
24. Plan showing Fixed and Movable Portions of Screen and Gearing to drive the Movable Parts.
25. Plan of Fixed Portion of Screen.
26. Section of Fixed Portion of Screen.
27. End Elevation of Fixed Portion of Screen.
28. Side Elevation of Fixed Portion of Screen.
29 and 30. Plan and Elevation of Movable Portion of Screen.

Figures illustrating Chapters VII., VIII., IX., X., XI., XII., XIII., XIV., XV., XVI.

PUMPING ENGINES AND APPLIANCES.

31. Tank swung below Cage.
32. Plan of Tank showing Clack in Bottom.
33. Tank, Trough, Settling Place and Drain.

34. Siphon connecting Two Sump Holes.
35. Effective Siphon placed Level.
36. Effective Siphon—Regular Inclination.
37. Defective form of Siphon.
38. Principle of the Siphon.
39. Plan of Bronze Clack, in use time of Hero, 200 B.C.
40. Elevation of Bronze Clack, in use time of Hero, 200 B.C.
41. Fire Engine of Bronze, in use time of Hero, 200 B.C.
42. De Caux's Appliance for producing a Fountain by the Direct Force of Steam.
43. Lord Worcester's Pumping Engine with Two Cylinders and Separate Boiler.
44. Showing Action of Lord Worcester's Pumping Engine with One Cylinder and Separate Steam Boiler.
45. Supposed Worcester's Pumping Engine.
46. Captain Savery's "Miners' Friend" drawing Water up to it and then forcing Water above it.
47. Newcomen's early Atmospheric Pumping Engine with Outward Application of Condensing Water.
48. Newcomen's later Atmospheric Pumping Engine with Condensation by Internal Jet.
49. Model of Newcomen's Atmospheric Pumping Engine in Glasgow University.
50. Leupold's High Pressure Pumping Engine.
51. Blakey's Pumping Engine, Boiler and Chimney.
52. Watt's Separate Condenser showing Injection, Air Pump, Foot Valve, Delivery Valve, Hot Well, Snifting Valve and Cistern.
53. Watt's Parallel Motion.
54. Watt's Single-acting Engine making Down Stroke.
55. Watt's Double-acting Engine making Up Stroke.
56. Watt's Diagram of Energy, illustrating Economy of Expansion of Steam.
57. Elevation of Cornish Pumping Engine working Single-acting and ready to commence the Indoor Stroke.
58. Elevation of Wrought Iron Beam of Cornish Pumping Engine.
59. Transverse Section of Wrought Iron Beam of Cornish Pumping Engine.
60. Elevation of Cornish Bull Pumping Engine arranged to work Double-acting and just commencing the Down Stroke.
61. Cornish Pumping Engine, Double-acting, with Beam below and Cylinder over the Pit.
62. Showing Arrangement of Pit Work for Single Plunger Lift.
63, 64, 65. Showing Ram and Chamber, Clack Boxes, Clacks, &c., for Plunger Lift.
66, 67, 68. Showing Pump Stock in Section, Elevation and Plan, and the Joint.
69. Elevation of Pump Rod Joint.

0. Section of Pump Rods and Plates forming Joint.
71. Elevation of Pump Clack open.
72. Section of Pump Clack closed.
73. Section of Single Beat Valve closed.
74. Section of India-rubber Disc Valve closed.
75. Section of Cornish Double-beat or Crown Valve closed.
76 and 77. Sliding Piece and Wind-bore for Running Lift whilst Sinking.
78 and 79. Showing Clack Box and Clack, Bucket and Bucket Piece, Working Barrel and Pump Rods of Open Lift.
80. Plan of Pump Bucket.
81. Section of Pump Bucket making Up Stroke.
82. L-leg Pumping Arrangement for working Single Bucket Lift, 150 yards high.
83. Side Elevation of Compound Differential Engine showing Pump Quadrants and Pump Rods.
84. Sectional Plan of Steam Cylinders of Compound Differential Pumping Engine.
85. Side Elevation of Steam Cylinders and Differential Valve Gear.
86. Longitudinal Section through Steam Chest and Valves.
87. Transverse Section of High Pressure Slide Valves.
88. Transverse Section of Low Pressure Slide Valves.
89. Plan of Differential Valve Gear.
90. Action of Differential Valve Gear, Beginning of Stroke.
91. Action of Differential Valve Gear, Light Load, Early Cut-off.
92. Action of Differential Valve Gear, Heavy Load, Late Cut-off.
93. Action of Differential Valve Gear, End of Engine Stroke.
94. Showing Horizontal Steam Pumping Engine Double-acting and Boiler placed Underground and raising Water from a Mine.
95. Longitudinal Section of Reservoir in a Mine, showing Shafts and Sump Holes, Water High.
96. Transverse Section of Reservoir in a Mine, showing Pumping Engine, Water Low.
97. Probable Concentric Section of Pipe cast Vertically.
98. Possible Eccentric Section of Pipe when cast Horizontally.
99. Old and Defective Form of Expansion Joint.
100. Section of suggested Expansion Joint Arrangement for Steam Pipes in Pit.
101. Outside Elevation of suggested Expansion Joint Arrangement for Steam Pipes in Pit.
102. Suggested Method of securing Column of Steam Pipes in Pit.
103. Suggested Method of securing Column of Water Pipes in Pit.
104. Plan of Method of securing Column of Water Pipes in Pit.

105. Showing simplest Arrangement of Condenser for Steam Pump underground.
106. Holman's Condenser for Steam Pump.
107. Hayward Tyler's condenser for Steam Pump.
108. Elevation of Condenser attached to Steam Pump.
109. Plan of Condenser attached to Steam Pump.
110. Blow-through Valve used when Condensers are attached to Steam Pumps.
111. Elevation of Evans' Cornish Steam Pump.
112. Sectional Plan of Evans' Cornish Steam Pump.
113. Plan of Evans' Patent Rotating Disc Valve.
114. Sectional Elevation of Evans' Rotating Disc Valve.
115. Evans' Horizontal Double-acting Cornish Ram Steam Pumping Engine.
116. Evans' Horizontal Direct-acting Cornish Piston or Bucket Steam Pumping Engine.
117. Section of Evans' Pump Piston or Bucket for Cornish Steam Pumps.
118. End Elevation of Evans' Pump Piston or Bucket for Cornish Steam Pumps.
119. Evans' Horizontal Double-acting Ram Pumping Engine.
120. End Elevation of Evans' Vertical Ram Steam Pumping Engine, with Fly-wheel.
121. Side Elevation of Evans' Vertical Ram Steam Pumping Engine, with Fly-wheel.
122. Evans' Horizontal Compound Condensing Pumping Engine.
123. Evans' Hydraulic Pumping Engine for Mines.
124. Evans' Underground Pumping Engine worked by Endless Rope and Clip Pulley.
125. Hydraulic Engines Pumping Water out of Dip Workings to Sump.
126. Hydraulic Engines pumping Brine.
127. Hydraulic Pumping Arrangement.
128. Section of Hydraulic Pumping Engine.
129. Side Elevation of Hydraulic Engine in which One Pipe answers for Driving Column and Delivery.
130. End Elevation in Section of Hydraulic Engine in which One Pipe answers for Driving Column and Delivery.
130*a* and 130*e*. Warner's Treble Ram Pumps.
130*b*, 130*c*, 130*d*. Warner's "Favorite" Steam Pump.

Figures illustrating Chapter XVII.

MINING MACHINERY AT WHITEHAVEN IN 1806.

131. Showing Plan of William Pit Rotative Machine.
132. Showing Side Elevation of William Pit Rotative Machine.

122 and 124. Showing End Elevation of William Pit Engine Machine.
125. Showing Side Elevation of William Pit Temporary Pumping Engine.
126. Showing Plan of William Pit Temporary Pumping Engine, showing Boiler, Chimney, Spare Boiler and Pit Shaft.
127. Showing End Elevation of William Pit Temporary Pumping Engine.

Figures illustrating Chapters XIX., XX., XXI., XXII., XXIII., XXIV., XXV., XXVI.

HAULAGE.

138. Jig-wheel in Elevation.
139. Jig-drum in Plan.
140. Pair of Vertical Hauling Engines.
141. Pair of Horizontal Engines.
142. Drum lagged with Timber.
143 Drum lagged with Iron.
144. Roller Pulleys fixed on the Floor.
145. Showing Roller Pulley and Frame in position.
146. Series of Vertical Pulleys placed round a Curve.
147. Pulley hung from Roof.
148. Arrangement for Changing the Direction of Hauling Rope by Separate Large Pulleys.
149 Fork behind the Gang of Tubs.
150 Bridle Chain under the Tubs.
151 Bridle Chain over the Tubs.
152 Plan of Hauling Engines and Hauling Gear placed below the Wagon way.
153 Plan of Hauling Road with Four Branches worked by Tail Rope Arrangement.
154 Section of Main Hauling Way.
155 Section of No. 1 Branch Way.
156 Section of No. 3 Branch Way.
157 Showing the Connection with a Branchway made, not round a Curve but at Right Angles, by passing the Rope round One Large Pulley
158 Self-acting Arrangement to detach automatically the Gang from the Hauling Ropes on reaching the Pit Shaft.
159 Shackle Jaws for connecting Rope in Tail Rope Haulage.
160 Hook for connecting Rope to Gang.
161 Method of connecting Rope to Main Rope.
162 Method of connecting Rope to Main Rope.
163 Method of connecting Rope to Main Rope.
164 Method of connecting Rope to Main Rope.

165. Vertical Engine to work Endless Chain Haulage underground.
166. Plan of Hauling Engine and Two Boilers for Endless Chain Haulage underground.
167. Spur Gear Arrangement communicating Power from Hauling Engine to any number of Endless Chains.
168. The Ordinary Clutch Box Arrangement for throwing Hauling Pulleys In and Out of Gear.
169. Foot for taking Wear and giving Chain a better Grip on Hauling Pulley.
170. Front Elevation of Main Hauling Pulley for Endless Chain and Small Guide Pulleys.
171. Side Elevation of Main Hauling Pulley for Endless Chain and Small Guide Pulley.
172. Branch Chain at End of Main Rope.
173. Branch Chain worked from Main Chain at some Intermediate Point.
174. Working a Branch Chain from a Main Chain by means of Spur Gearing.
175 and 176. Elevation of Iron Tub for Endless Chain Haulage.
177. Plan of Self-acting Curve in Endless Chain Haulage.
178. Elevation of Self-acting Curve in Endless Chain Haulage.
179. Endless Chain Haulage at Coltness.
180. Automatic Stop Block in Endless Chain Haulage at Coltness.
181. Plan of Driving Gear, showing Tightening Pulleys and Arrangement for obtaining the Needful Friction.
182. Elevation of Driving Wheel and Tightening Gear.
183. Elevation of Tightening Arrangement. Endless Rope Haulage.
184. Clamp Attachment for Endless Rope Haulage under.
185. Method of Attachment of Tubs to Endless Rope under.
186. Method of Attachment of Tubs to Endless Rope over.
187. Attachment to Endless Rope over.
188. Plan of Endless Rope Haulage Arrangement, showing Main and Branch Ropes.
189. Elevation of Endless Rope Haulage Engines and Haulage Ropes in Pit Shaft.
190. Elevation of Engines and Gearing for Endless Rope Haulage.
191. Plan of Engines and Gearing for Endless Rope Haulage.
192. Arrangement of Pulleys and Clutch Gear for Hauling Gear.
193. Working Part of C Hauling Pulley when new.
194. Working Part of C Hauling Pulley after several Years' Wear.
195. Working Part of C Hauling Pulley as Amended with Going-on side larger in Diameter than Coming-off side.

196. Section of Driving Pulley for Endless Rope Haulage.
197. Elevation of an Endless Rope Haulage Arrangement.
198 and 199. Fisher's Clip Hook for Endless Rope Haulage.
200. Elevation showing Attachment to Hauling Rope by Fisher's Clip Hook.
201. Elevation of Tubs passing round Guide Pulleys of a Curve.
202. Plan showing Curved and Guide Pulleys on which the Hauling Rope works.
203. Fisher's Patent Friction Clutch Gear—Side Elevation.
204 and 205. Fisher's Patent Friction Clutch Gear—Sectional Elevations.
206 and 207. Fisher's Patent Friction Clutch Gear—Sections.
208. Fisher's Patent Friction Clutch Gear—Elevation of Wheel, showing Pins fixed in the Arms.
209. Fisher's Patent Friction Clutch Gear—Section.
210. Plan of Hauling Engine with Driving Gear and Tightening Gear.
211. Elevation of Hauling Engines with Driving Gear and Tightening Gear.
212. Forged Steel Wheels—Eyre's Patent.
213. Elevation of Compound Hauling Engines, showing Position of Foundation Timbers.
214. Plan of Compound Hauling Engines, showing Position of Drums and General Arrangement of Gearing.
215. End Elevation of Compound Hauling Engines, showing Steam Receiver and Timber Foundation.
216. Elevation of a Horizontal Engine with Joy's Valve Gear attached.
217. Plan of a Horizontal Engine with Joy's Valve Gear attached.

Figures illustrating Chapter XXVII.

HADFIELD'S STEEL CASTINGS FOR COLLIERY USE.

218, 219, 220, 221. Hadfield's Self-oiling Wheels and other Steel Castings for Colliery Use.

Figures illustrating Chapter XXVIII.

AIR COMPRESSING MACHINERY.

222. Sectional Elevation of Air Compressing Beam Engine.
223. Plan of Arrangement of Spherical Clacks in Air Piston of Air-Compressing Engine.

224. Longitudinal Section of Horizontal Air Compressing Engine with no Circular Motion.
225. Elevation of Horizontal Air Compressing Engines with Circular Motion.
226. Plan of Horizontal Air Compressing Engines with Circular Motion.
227. Longitudinal Section of an Air Compressing Cylinder, showing Water Jacket and Inlet and Outlet Valves.
228. End Elevation of an Air Compressing Cylinder showing Inlet and Outlet Valves.
229. Inside Elevation of Outlet Air Valve.
230. Section of Outlet Air Valve.
231. Inside Elevation of Inlet Air Valve.
232. Section of Inlet Air Valve.
233. Plan of Sturgeon's High Speed Air Compressor.
234. Sturgeon's High Speed Air Compressor. Section of Air Cylinder Cover showing Inlet and Outlet Valve.
235 and 236. Pair of Air Compressing Engines by Walker Brothers.

THE MECHANICAL ENGINEERING OF COLLIERIES.

VOLUME II.

CHAPTER I.

APPLIANCES AT ABRAM COLLIERIES AND HAYDOCK'S REVOLVING TABLES.

The Abram Collieries—Seams of Coal worked and Depths—Plant at the Various Pits—Fox and Hopkinson's Corrugated Boiler Flues—Corliss Type of Winding Engine—Weight of Air passing through Mines in Twenty-four Hours—Daily Output of Coals—Horse Power of Engines and Boilers—Manufacture of Coke—Generation of Steam from Waste Heat of Coke Ovens—Ormerod's Safety Links to prevent Accidents by Overwinding—Construction of Pit Banks—Steam Lifts—The Abram Company and Education Elementary and Technical—Growing Necessity for Picking and Cleaning and Separating Coals—Special Importance at Abram—Mr. William Haydock and his Revolving Tables—Principles and Construction and Advantages of his Appliances—Their Probable Extensive Adoption.

In Chapter VII., Volume I., reference has been made to the Bickershaw Collieries, their equipment, and a description given of an effective brake, the invention of one of the officers. The collieries to which this Chapter will refer adjoin Bickershaw, and we shall have occasion to mention a useful invention for colliery purposes, the credit of which belongs to one of the staff at Abram Collieries.

The history of Abram Collieries only dates from those roaring times in the coal trade (1872-73-74) when sellers regulated the prices, and consumers were glad to purchase almost at any cost. The oldest of the several

pits now forming the concern of the Abram Coal Company only looks back upon an existence of some dozen years, and the newest pit has not as yet got fairly to work.

Fortunate in the possession of extensive and valuable seams, the owners have displayed commendable enterprise in sufficiently equipping them for their work. The mines worked are five in number, namely, the Wigan "Five-feet," 266 yards deep; the Wigan "Four-feet," 292 yards deep; the Wigan "Nine-feet," 320 yards deep; the "Haigh Yard," 520 yards deep; and the "Arley," 650 yards deep. And each of these seams has, or will soon have, separate shafts and separate winding appliances.

The No. 1 pit raises from a depth of about 290 yards, the engines being 26-in. cylinders and 5 ft. stroke, and the winding-drum 15 ft. diameter. Four tubs, each weighing with its contents 10 cwt., are raised each winding, the cage weighing 17 cwt. and the rope about 30 cwt., making a gross load of nearly 4½ tons.

The No. 2 pit winds from a depth of 330 yards, the engines, drum and load being about the same as for the No. 1. The provision for ventilation is made at a separate pit, the No. 3, in the shape of a large Guibal fan, 46 ft. diameter and 12ft. wide, driving which alternately are two separate engines with 36in. low pressure cylinders, 20 in. high pressure cylinders and 36 in. stroke, producing, if required, over a quarter of a million cubic feet of air per minute. In connection with the No. 1 and 2 pits there is a pair of air-compressing engines, the steam and air cylinders being of equal diameter—28 in.—and the stroke 5 ft., the pressure of air obtained being 70 lb. For these air compressors and the winding engines at Nos. 1 and 2 there are seven Lancashire boilers, besides three boilers similar in character at No. 3, to provide steam for the fan. This comprises what we should term the older portion of the colliery, if the term old can be used at all in connection with so modern a plant.

No. 5 winds from a depth of 650 yards, with engines 40 in. cylinders and 7 ft. stroke, the drum being 24 ft. The load consists of 56 cwt. coals, 24 cwt. tubs, 52 cwt. cage, and 60 cwt. rope, being a total load to start from bottom of nearly 10 tons, and a winding occupies 45

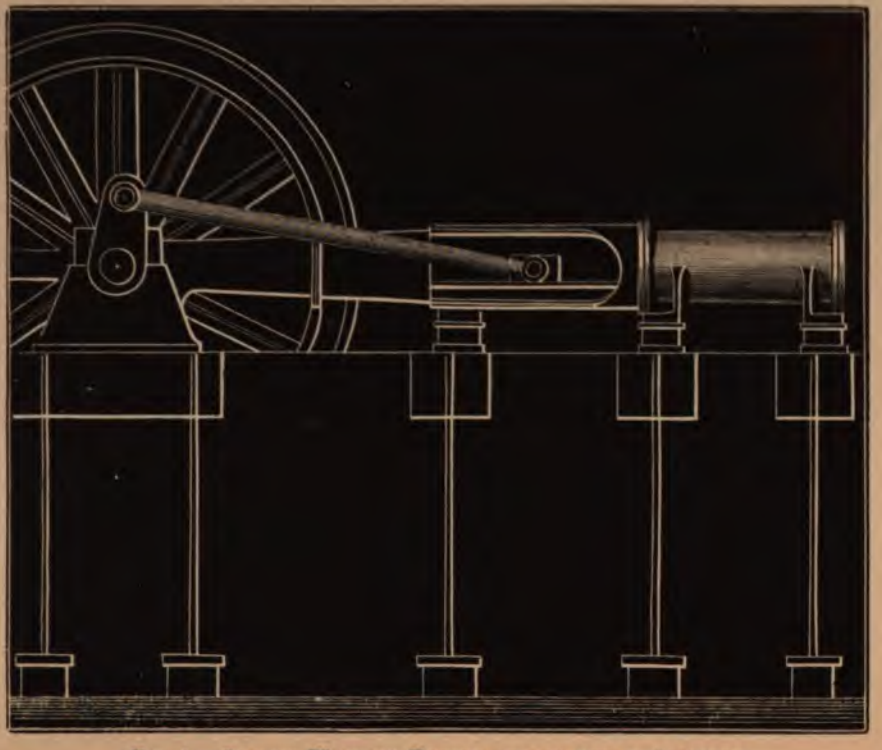


FIG. 1.—CORLISS WINDING ENGINE AT THE ABRAM COLLIERY.

[*To face page* 3.]

seconds, giving an average speed of winding rope 30 miles an hour, and the output equals 1,000 tons per day.

No. 4 pit is not yet fully at work, but is arranged to wind from a depth of 530 yards, with engines 32 in. cylinders and 6 ft. stroke, the drum being 18 ft. diameter. For ventilating No. 4 and 5 a Guibal fan is provided similar in itself and its engines to the one described as being at No. 3. There is a pair of air-compressing engines, with steam cylinders 23 in. and air cylinders 25 in., the stroke being 5 ft. and the air pressure 70 lb. At No. 4 and 5 pits, being the more modern part of the plant, there are eleven Lancashire boilers, some of which are fitted with Fox and Hopkinson's corrugated flues. All the boilers have a blowing-off pressure of 70 lb. The headgears are all of wood, and the pulleys large in diameter, those at No. 1 and 2 being 13 ft., No. 4, 16 ft., and No. 5, 18 ft. The drums are all cylindrical, and the ropes parallel, except those at No. 5, which are taper. With the exception of one pair, all the winding engines are of the ordinary type, horizontal, but the engines at No. 4, which have not yet been put to work, and which are sketched in fig. 1, are constructed on what is known as the Corliss type, as regards the bed plate, in which the only difference consists. The ordinary bed-plates for horizontal engines are dispensed with, and the drum shaft rests upon pedestals reaching to the pillar. The end of slides and both ends of cylinders are supported upon brackets also resting upon the pillars. Probably something will be saved in weight, and possibly good results in working will be obtained, but the engines can scarcely be termed fair to look upon. This view may, perchance, be attributed with some truth to foolish prejudice in favour of the style with which the colliery eye has been accustomed. The Abram people are fortunate in having no water to deal with, and their engines, therefore, are confined to winding, ventilating, air-compressing, and hauling. The output, will, when all the four pits are at work, amount to not less than 3,000 tons per day, and to give an idea of the weight of air passing through the mines we may say that with the two Guibal fans doing what they are easily capable of—namely, 600,000 cubic feet of air per minute, the weight of air each twenty-four hours will amount to nearly 30,000 tons,

being 20 tons of air for each ton of coal raised. The total horse-power of boilers will amount to between 4,000 and 5,000, and that will give a sufficiently near approximate of the horse-power of the engines. There is no attempt to counterbalance either by spiral drum or balance rope. The drums are all parallel, and consequently the load to start in every case is considerably in excess of the load at any other part of the winding. The engines are by various makers—namely, Wilkinson, Coupe, Daglish, and Walker, the latter predominating. None of the engines have back piston rods, except those with 40-in. cylinders, and probably no harm would result from the removal of these. The No. 5 engines have a steam brake, No. 4 a Burn's brake, which gives much satisfaction, and the others ordinary foot brakes. Twenty-one Lancashire boilers—of which number all, with the exception of perhaps three, are working at one time—must have a large consumption of fuel, representing a good many thousand pounds sterling each year. It is not surprising, therefore, that a large number of coke ovens will shortly be erected to manufacture from the Arley slack coke, for which there is a good local demand, and it is proposed to utilise what would otherwise be waste gases from coke ovens for generation of steam. Wherever coke is made these gases should be used in this way. What is now successfully accomplished at many works might with advantage to proprietors be made a universal practice. The stages are covered in, so are the boilers, and the whole winding appliances are fitted with Ormerod's safety links. The argument is sometimes used now, and some years ago was generally used amongst colliery authorities, that the application of detaching hooks would make winding engine men careless. At Abram there has never been one case of overwinding since the detaching hooks were put on, which implies either that the objection is not well founded or else Abram possesses exceptionally good enginemen.

The pit banks are built up on cast-iron columns, some 20 feet in height, and the level of pit bank about agreeing with floor of winding-engine houses. This arrangement is not uncommon, nor the height unusual, but the means provided for enabling all the work to be done on the stage level is not quite so common. A steam lift, which com-

prises little more than a good true pump stock and a piston working in it, is placed at each pit bank. This enables all the timber and bricks and rails, and other materials that have to go underground to be raised from the railway or ground level and despatched down the pit from the stage, thus avoiding the need of two landing places at the surface.

Also in filling fuel from stock a steam lift similar in character can easily be conveniently placed, and proves of great service. It enables all the fuel from stock to pass over the screens just as if it was coming direct out of the pit. These unpretentious machines are effective, economical, and occupy little space.

The Abram Coal Company have not been content with simply sinking pits and opening out mines, and thus providing employment for several hundred people, but they exercise something like paternal care over those whom they employ. They are substantial supporters of the Wigan Mining and Mechanical School, which affords to some extent a technical training for their officers, and recently commodious buildings have been erected for the elementary education needed by the rising generation in connection with their works. Well-arranged workshops enable the firm to keep their three locomotives, their thousand railway wagons, and the whole of their plant in proper repair, and altogether the Abram Collieries afford a good example of the adaptation of modern appliances tending to safety, expedition, and completeness.

But something more is needed at a colliery nowadays than good ventilators for safety, and good engines for winding and hauling, and good boilers for steam generation. The coal when raised to the surface cannot, unless in some very exceptional cases be thrown into the market. These are not the days of the coal famine; people will not buy anything if it looks like and is called coal. We must separate one class of fuel from another; we must keep the slack away from the round, and send the fuel away free from dirt. Attention to these points has in these latter days become a very important matter, and colliery proprietors are getting more and more alive to the fact that more attention at the pit after the coal reaches the surface will so much increase its value in the

market as to represent a profit. There are many ways of accomplishing this, and some of them have already been described. Without attacking other arrangements there is room and justification for presenting to public notice another method of accomplishing the desirable result of sending coal away in good marketable condition. The Abram people, although, as has been said, possessing good seams, have had their difficulties to contend with. One seam, the "Four-feet," is, to some extent, a mixture of coal and cannel, and whilst it is important to the purchaser not to have the inferior article sold along with its superior it is also to the interest of the seller not to allow the better quality to go away with the inferior stuff. Also, some of the seams have more or less of dirt, and no colliery proprietor is doing justice, either to himself or his customer, in despatching coal with dirt amongst it. The Abram people have recognised these difficulties, and have grappled with them, in the person of their engineer, Mr. William Haydock (to whom belongs the credit of the simple steam lift already referred to), whose efforts generally to effect improvements in colliery machinery deserve a word of commendation in these columns, and whose revolving tables for facilitating the screening and picking and assorting of coals we propose to say something about. Figures are given which, it is hoped, are sufficiently clear to explain the apparatus and to create a thirst for further information. Fig. 2 shows the revolving table and vertical shaft and rollers and driving gear in elevation. Fig. 3 shows the table and rollers and curved scrapers in plan. Fig. 4 gives a general elevation of two screens feeding the revolving table, and fig. 5 shows two shoots delivering the coal from the table into the wagons. In fixed screens, as described in Chapter XI. (Volume I.) the coals pass down the screens, the round passing over the bars into one wagon and the slack through the bars into another wagon. Slack is not thoroughly taken out of the round; some round passes away with the slack. Dirt cannot be thoroughly picked, and tramping about in the wagons breaks the coal.

Revolving riddles screen efficiently, but do not assist—in fact they retard—the picking. Travelling bands do nothing for screening, but by extending the operation over

a long distance picking can be accomplished. Haydock's arrangement consists of a revolving table, which receives the coal from the screen and deposits it in the wagon. The speed of revolution is regulated to suit the amount of picking to be done. When this is the only operation, the coal has simply to make its way from the screen to the wagon, and the dirt is taken out during revolution. When the machine has to separate two qualities of fuel, such as cannel and coal, one quality is allowed to revolve on the lower level, and finds its way into one wagon, the other quality is picked out and placed on the higher level, also revolving, and is swept into its wagon. Should there be more cannel than coal, the latter is picked out; if less cannel than coal, the former is picked out, always having the least quantity to lift out. Should, in addition to picking dirt and assorting the fuels, screening be needed, the revolving table is perforated like a screen or riddle, and allows the slack to fall through. The curved scrapers are fixed, that is, they have no motion of revolution, but they can be moved into the sweep of the circumference of the table, or can be raised up out of the way if required.

The tables are keyed to vertical shafts which receive motion from a small engine, which is usually arranged to work several machines, each machine being arranged with friction cones to be easily connected or disconnected. The better plan, perhaps, is to connect the power to each table by bevel wheel below, but the power, if more convenient, can be communicated to any other part of the vertical shaft. The vertical shaft rests on a central point, and the table revolves upon four rollers, and the whole being neatly supported and balanced, scarcely any power is needed to work them. One small engine with a 6 in. cylinder will drive half-a-dozen. There is scarcely any wear upon the table, just enough to get a smooth surface, and accordingly they will wear almost for ever.

We will suppose a mixture of cannel and coal to be dealt with, the cannel predominating. This means that we pick out the coal. The mixed fuel has passed down the screen and been deposited on the lower or outer part of the table. All fuel passing round on this part of the table is swept off by the fixed curved scrapers down the cannel shoot into the cannel wagon. The coal is picked

out and deposited on the inner and higher part of the table, which also revolves. All fuel on this part of the table is directed by the fixed curved scrapers down the coal shoot into the coal wagon. Mr. Haydock contends that his appliances have the following advantages:—(1.) The first cost is small, there being no complicated mechanism. (2.) The amount of driving power is very slight, and can be obtained either from a special engine or an engine doing other work. (3.) No repairs are needed, because the machine cannot get out of order. (4.) They enable dirt to be picked better than any other method, the arrangement being more convenient and more concentrated than a travelling band. (5.) They assist the screening, which travelling bands do not. (6.) They enable different classes of coal to be assorted, and travelling bands do not assist in that portion of the work. (7.) They avoid all trampling and breaking of coals in the wagons. (8.) They enable a short screen to give more efficiency than the present long screens, because the revolving table supplements the action of the screen. The apparatus is not the result of a brilliant flash of genius by some engineer of national reputation, nor does it represent the combined ingenuity of a score of thinkers and workers. The idea, and the putting that idea into practical form, are alike the work of the engineer whose name is associated with it. The circumstances of Abram collieries required some such contrivance; necessity was once again the mother of invention, and Mr. Haydock, with that knowledge and interest in his work which characterise our colliery engineers, set his wits to work, and the result is what we have described. His employers have expressed their confidence in him at first by trying them, and their satisfaction afterwards by putting them to all their pits. Outsiders in Lancashire and Yorkshire have not been slow to avail themselves of a simple means at a slight expense to increase the market values of their coal and maintain their reputation as sellers of coal free from dirt and slack. But they would be more extensively used if it were more generally known that such appliances were in existence. The writer has on many occasions watched them at work, and expresses his unhesitating approval of their efficiency. It was not possible, with

pressure of other matter, to find an earlier opportunity for noticing them in Vol. I., and an apology is, perhaps, due to Mr. Haydock, the inventor, and those who might have become his customers had they known of his appliance earlier. But, in any case, no apology is needed for placing amongst a series of articles professing to deal with colliery mechanical engineering some descriptive remarks on the appliances at the Abram collieries, and especially Haydock's revolving tables for screening, picking, and assorting coals.



CHAPTER II.

THE EXHAUST STEAM INJECTOR.

The Injector of M. Giffard—Mr. Stewart's Experiments—Papers by Mr. John Robinson—English Engineers incredulous—Suggested Theories—Mr. Robinson—Sir Frederick Bramwell—Sir William Siemens—Professor Goodeve—The Action of the Injector explained in the word "Concentration"—The Exhaust Steam Injector of Hamer, Metcalfe, and Davies—Experiments made by Mr. Saville—Its Introduction to the Public in 1880—How attached to an Engine and Boiler—How it works—Particulars of two Elaborate Experiments showing Heat gained and Water saved—Its Advantages over other Arrangements of Heating Feed-water—Needs no Attention, and can be applied to all kinds of Non-condensing Engines—Testimonials as to Efficiency from all parts of the Country and from Abroad.

A GENERATION ago, M. Giffard, of Paris, invented, and had constructed, an "automatic injector" to feed steam boilers by a self-acting apparatus, employing the direct application of steam from the boiler without the intervention of machinery, and ready for action at all times, independently of the working of the engine, and free from the liability to derangement and the wear-and-tear incidental to machinery in motion. Mr. Stewart, of Manchester, procured an injector from France in 1859, the year of its production, brought it to England, and tried it upon a stationary boiler at his works. It was subsequently put to work upon a ballast engine on the St. Helen's Railway, where, in the course of a few days, the driver was able to dispense with the use of his engine-pumps, and to maintain the level of the water in the boiler by the injector alone. A larger injector was then tried upon a goods engine upon the same railway, which proved entirely successful. In 1860 Mr. John Robinson read two papers on the subject,* and the result was several interesting discussions and a large sale of the injector. Experiments at that time showed that the injector

* *Transactions* Institution Mechanical Engineers.

would work at all pressures up to the maximum working pressure of the boiler, 110 lb. per square inch, and would draw water from the tender up to the temperature of 110 degs. Fahr., and that neither the sudden application of the brake nor any shock produced in passing bad points or in shunting interfered in any way with its efficient working. A difficulty arose when the water in the tender had become hot and at the same time very low in level, under which circumstances conjoined the degree of vacuum capable of being produced in the water chamber of the injector was not sufficient to lift the water to the height at which it was placed, 29 in. above the foot-plate. The inconvenience, however, was readily obviated by lowering the injector so as to bring the water entrance within a few inches of the level of the bottom of the tender. In using the injector no difficulty was experienced in so regulating the openings for steam and water as to produce a constant and regular supply of any required quantity of water to the boiler without waste from the overflow pipe.

Such was the result of experiments in 1860, and the "injector," about which even distinguished engineers at first said "nonsense," became exceedingly popular, and was rapidly applied, not only to locomotives, but all kinds of stationary boilers, and at the present time very many thousands are in use. This was sure to come about, because the advantages were so striking. Space hitherto occupied by pumps was saved, the power required to work the pump was economised, and the wear and tear of the parts of the pump through which the power was transmitted was entirely avoided. And the water level could easily be maintained at any desired height, whether the engine was moving or not; and the steam often blown off when standing could be used for forcing water into the boiler. It was found that water could be forced into a boiler by the injector when the pressure was not below 5 lb. per square inch; that the temperature of the feed-water might be raised to 148 degs. Fahr., and that surplus power was developed by the instrument available for forcing water into a boiler at a higher pressure than the one from which the steam was obtained—the injector having been effective with steam of 24½ lb. above the

atmosphere in forcing water into a boiler at 48½ lb. pressure.

Mr. Robinson, an ex-President of the Institution of Mechanical Engineers, suggested the following theory, according to which the injector was supposed to act. Steam or water escaped from a boiler into the atmosphere at a velocity proportioned to its pressure or density. If a pipe conveying steam were turned directly back into the water of the same boiler, equilibrium would ensue, and no effect be produced. But if a break were made in the continuity of the pipe, so as to leave an interval open to the atmosphere, the steam would rush from one pipe and the water from the other, at velocities proportioned to their respective densities. In the injector the feed-water chamber was placed at this break, and the arrangement accounted for the power of the steam to overcome the resistance to its entrance, and so force its way into the boiler. Such was Mr. Robinson's theory.

Mr. (now Sir Frederick) Bramwell, another ex-President of the Mechanical Engineers, explained the action in the following manner:—It was due to the velocity imparted to the feed-water by a jet of steam, and might be illustrated by supposing a cistern of water with several feet head to supply a jet in the position of the lower part of the injector, and another jet from a higher cistern to be then brought opposite to the first, in the position of the upper part of the injector, when the greater velocity of the upper jet would necessarily overpower the lower one, and the water would force its way into the tube of the lower jet. In the case of the injector, if the velocity imparted by the jet of steam to the feed-water in the upper jet were greater than that at which the water would escape from the lower tube if unopposed, the water must be forced into the boiler. And since the velocity of the steam was so much greater than that of the water issuing from the same boiler, in consequence of its greatly reduced density, the steam jet was able to impart a sufficient excess of velocity to the feed-water to force it into the boiler.

A few months afterwards the late Sir William Siemens, who also in his day was President of the Mechanical Engineers—and no more able or more genial man ever

occupied any presidential chair—gave his idea on the subject, with special reference to the rise of temperature in the feed-water by its passage through the injector. If 1 lb. of steam in motion were mixed with 2 lb. of water at rest, the result produced would be 3 lb. put in motion at one-third the original velocity of the steam. The velocity of water or steam issuing into the atmosphere from the same boiler is equal to that acquired by a falling body in falling through the height of a column of the same water or steam giving the same effective pressure. And since the velocity acquired by a falling body is proportional to the square root of the height through which it fell, it follows that the velocity of the water and the steam would be proportional to the square roots of their relative volumes. And as the volume of steam with one atmosphere effective pressure is 860 times that of water, it would issue with square root of 860, or twenty-nine times the velocity of the water from the same boiler. Hence, the steam issuing would just balance twenty-nine times its own weight of water trying to issue from the boiler; and assuming the total heat of steam at 1,200 degs. Fahr., and the original temperature of the feed at 100 degs., the rise of temperature of the feed would be $1,200-100=1,100$, $29 + 1 = 30$, and $1,100 \div 30 = 37$ degs. Fahr. rise of temperature for one atmosphere effective pressure—with two 44 degs., with three 50 degs., with four 55 degs., and so on.

Professor Goodeve, writing on the subject a good many years later, says the explanation of the action of the injector is to be found in the conversion of the motion of heat. The steam has a velocity many times greater than that of the water. If the jet of steam could be condensed into a fine liquid line, the velocity of its molecules would not be changed, and this liquid line would be moving at such a high velocity as to pierce any jet of water. This result cannot altogether be produced; but what does happen is the same in character, although less in degree.

The whole theory of the injector is comprised in one word, "concentration." Suppose we had a cistern containing water, with a nozzle upon the side of it near the bottom, from which water could issue horizontally in a jet. Assume the jet to be opposite to an orifice in an empty

cistern parallel with the first. We know that the jet of water would enter that orifice, and that the water would accumulate in the cistern which the jet entered, and that the jet would continue to enter until the accumulated water in the second cistern caused the jet to have such an opposition that it could not enter. Experiments by Mr. Froude have proved that when you have once got the water into motion, if you will allow a sufficient difference of head between the two cisterns to compensate for the resistance caused by the friction in the tubes through which the water passes, the water will, if you have a proper nozzle, continue to enter into the second cistern when it is full up to the height of the first one, minus the difference expressing the friction. We may, therefore, get the water entering the second vessel very nearly to the height from which it issued from the first. But suppose the water in its passage across the imaginary space from the vessel from which it flowed to the one into which it is to enter could by some process be converted into mercury, the same weight of mercury as was equal to the weight of water. We should diminish the area of the stream to one-fourteenth, so that the stream which came out of an orifice of a square inch, when converted into mercury, would enter into the other tank through an orifice of one-fourteenth of a square inch; but the stream being of the same weight, and flowing with the same velocity, would concentrate on that one-fourteenth square inch the whole of the energy which, if it remained water, would otherwise have been applied on the square inch; and thus, by this act of concentration, there would be fourteen times the power per unit of surface, and it would come with the same effect as if it came from fourteen times the height. With such a concentration it would enter the second tank, not merely against a head equal to that from which it came, but against a head very nearly fourteen times as great. Therefore it is clear, if we could convert water into mercury we could get the power to enter against a very excessive pressure, to re-enter its own tank and much more.

But instead of taking water issuing from a tank, if we take steam issuing from a boiler, and let that steam be concentrated by being condensed; having condensed it, it

is concentrated not only fourteen times, as in the comparison between mercury and water, but 144, or 388, or 1,696 times, or whatever may be the proportion of the particular steam to water. By this concentration we have an enormous power, competent not only by itself to re-enter the boiler from which the steam came, but a power so much in excess of this as to be able to take along with it the water employed in producing the concentration, that is, the condensation of the steam. In this way the injector introduces into the boiler the steam that came out of the boiler and the water that condensed that steam.

It has been, if not essential, still desirable to say this much by way of introduction, to make matters clear, because although the exhaust injector goes far beyond what M. Giffard or any of his admirers ever dreamt of, still Giffard's injector may be considered the worthy parent of the more modern contrivance about which we now write, and which is illustrated with sufficient clearness in figs. 6, 7, 8, 9, 10, 11.

The injector delivered water into boilers by the power of live steam, and the greatest difference in pressure at which this could be accomplished was two and one—that is to say, the pressure of steam to work the injector must not be lower than 5 lb., and the pressure of water to be faced must never be greater than twice the pressure which works the injector. The exhaust injector, except in very special cases, needs no live steam, derives its power from ordinary exhaust, and with this as low as the atmosphere will oppose pressure, and overcome it, of 60 lb. or 70 lb. per square inch. The appliance was only made public some four years ago, but endeavours to bring such contrivance to perfection have extended over a considerable period. The inventors, Messrs. Hamer, Metcalfe, and Davies, knowing they had a good thing in hand, were determined it should be practically perfect when presented to public notice. Under the careful supervision of their able and indefatigable engineer, Mr. Saville, countless experiments were made, extending over a considerable period, and at last, towards the end of 1880, the exhaust injector was at everybody's service, and in the space of a few years the public have expressed their approval in the form of thousands of orders.

Fig. 6 gives an outside elevation, and fig. 7 a section of the apparatus; fig. 8 shows its ordinary application, and fig. 9 its application in very special cases, where the pressure in the boiler exceeds 75 lb. per square inch. A very fair idea may be obtained of the construction of the exhaust injector from the figures, and a few words will suffice by way of explanation. The injector is placed at some convenient distance from the main line of exhaust pipes, and of course the nearer the range of boilers the better. There often is in exhaust ranges at least one elbow, and a good arrangement is to have the exhaust injector connected at that point. The connection with the main exhaust pipes is a small pipe proportioned according to work to be done. An idea prevails, where the injector has not yet been applied, that its application entails back pressure upon the engine; but no alteration is made in the exhaust pipes— they are not stopped up—all the exhaust is not compelled to pass through the injector. The pipe is tapped into the exhaust pipes anywhere, and the exhaust can, and does, pass on its way free and unfettered, the injector supplying its own wants without retarding anything. In most cases, especially where back pressure upon the engines is very slight, the exhaust injector practically leaves matters in that respect as it finds them; but in engines used at collieries for winding, which work intermittently and at a high speed, the back pressure upon the piston is never less than several pounds per square inch, and in such cases the exhaust injector not only does not increase the back pressure, but lessens it.

To set the exhaust injector to work, communication is simply opened with the exhaust and with the feed-water, the exhaust arrangement having already been explained, and the feed-water tank simply placed slightly higher than the injector. It is well known that no injector will lift water more than a few feet, that is the feed-water cannot be much below the injector. The exhaust injector would probably do almost as much in this direction as its predecessors. But the inventors wisely instruct that in all cases the arrangements shall be such as will allow the feed-water to fall. The exhaust enters the top of the injector, and passes into a conical nozzle, having within it a fixed conical spindle, the object of which is to concen-

trate and direct the flowing exhaust into a circular jet by the time it meets the cold feed water, and thus precipitates condensation. The cold feed water enters at the side of the injector near the top and surrounds the steam, passing through the conical chamber, thus commencing the action of condensation at once. The exhaust and water meet in the condensing chamber, which forms the upper part of the hinged nozzle. This hinged nozzle is very important, and, in fact, imparts to the exhaust injector its automatic action. When not working, the nozzle hangs back, thus allowing ample space for the steam and water to meet. When the meeting has taken place, condensation being instantaneous, a partial vacuum is formed, and the hinged nozzle is drawn from its lying-back position, and the space through which the combined exhaust and water have to pass made contracted. This, taken together with explanation at beginning of this chapter on injectors generally, is the entire action, and it is as simple as it is beautiful.

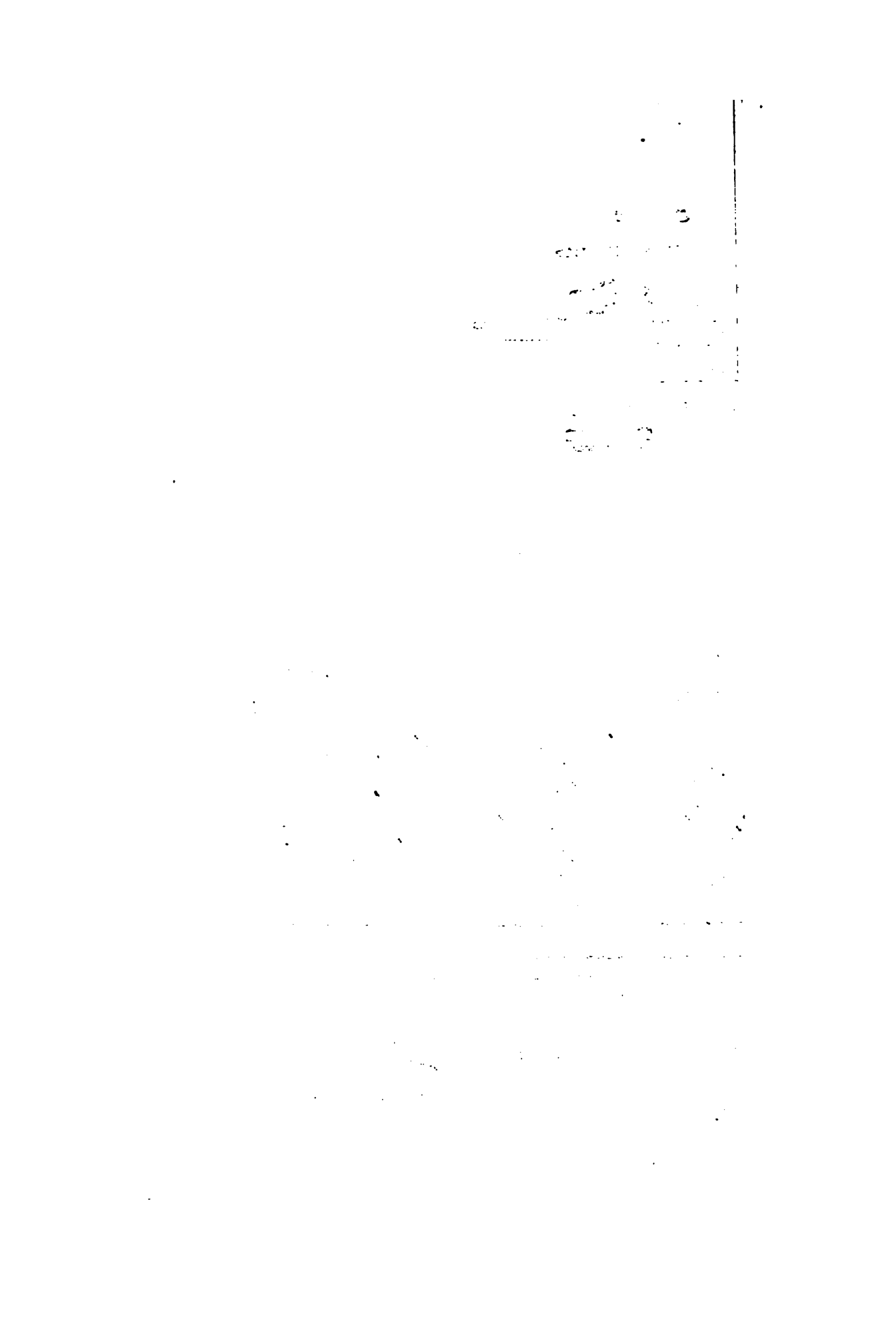
The reason that the exhaust injector works so well, and why it works at all, is that the construction inwardly is eminently adapted for instantaneous condensation, forming a fairly good vacuum. We all know the enormous velocity with which steam will rush into even an imperfect vacuum, and the momentum consequent on this high velocity enables the liquid lines into which the water and exhaust have been formed, to pierce an extraordinarily high pressure. Hence the efficiency of the exhaust injector, and possibly these few simple words of explanation will answer the writer and the reader's purpose as well as a whole volume.

Experiments were made with what is known as a No. 12 exhaust injector, which proved amongst other things that the minimum increase in temperature imparted to the feed-water by passing through the injector is 100 degs. Fahr., and if more than this heat be added there will be less saving in water. No. 1 experiment showed that with feed-water at 68 degs., 2,490 gallons per hour were taken from the feed-water tank, and 2,736 gallons per hour were delivered into the boiler at a temperature of 168 degs. giving increased temperature 100 degs., and saving of water 246 gallons per hour, the number of heat units saved per hour being $2,490 \times 10 = 24,900 \times 100 = 2,490,000$.

No. 2 experiment took feed-water from the tank at the same temperature, 68 degs., the quantity being 2,280 gallons per hour, and the quantity delivered into boiler was 2,561½ gallons per hour at a temperature of 190 degs., the increase in temperature being 122, the saving in water being 281½ gallons per hour—the heat units saved being 3,125,030. That is, we simply reckon one heat unit as the heat required to raise the temperature of one pound of water one degree. And each gallon of water is ten pounds.

It may be urged that there are other arrangements of a simple character for heating feed-water which raise the temperature quite as much, and use over again a considerable quantity of water. This is so, but requires large structures, with or without tubes, and also necessitates a pumping engine, which has to be worked with live steam. The exhaust injector is pumping engine and heater combined, and needs no live steam unless the boiler pressure of steam exceeds 70 pounds, in which case a slight jet of live steam is required. Those heaters which enable water to be used over and over again put back into the cylinder impurities which injure the engine and affect its working. The exhaust injector allows the heavy and impure exhaust steam to pass on, and snatches for its use only that which is lighter and purer. It can be and has been applied to all kinds of work to all kinds of engines, and is efficient for continuous working engines, such as blowing engines, fan engines, pumping engines, or for those which, although not continuous, run for several minutes at a time. It goes further, and shows good results attached to winding engines, provided the period of winding is of reasonable duration. It needs no attention, and being absolutely automatic, starts and stops with the engine to which it is connected. There is a little tendency to waste water between the windings, which can be entirely obviated by attaching a simple arrangement of such a character that the supply of feed-water opens and closes with the starting and stopping of the engine. Figs. 10 and 11 show an application to locomotives.

The writer would fain have quoted a few expressions of satisfaction from amongst the many hundred testimonials received from more than one country and more than





one continent, and which speak as to the saving effected in water and in fuel—the satisfaction is expressed in unhesitating terms, and substantial praise awarded in giving fresh orders, which, after all, are the best certificates of approval—but will content himself with expressing his confidence in the efficiency of the exhaust injector and his belief that a continuously prosperous future lies before this, one of the most efficient, simple, and successful inventions of the nineteenth century.

Even already, whilst scarcely old enough to be generally known, it is applied to all classes of high pressure steam engines, and in use more or less in every part of the civilised world.

CHAPTER III.

AUTOMATIC EXPANSION GEAR FOR WINDING ENGINES.

Conditions which good Winding Engines should fulfil—Modern Winding Engines not Economical—Extravagance of Non-condensing and Non-expansive Engines—Difficulties in applying Expansion Gear to Winding Engines—The Automatic Expansion Gear of Mr. Arthur J. Stevens—The Object, the Method of Action, and Advantages—The Great Western Colliery, Pontypridd—Diagrams from the Great Western Colliery Engines, with and without Expansion—The Astley and Tyldesley Collieries—Mr. G. H. Peace—Description of Winding Plant—Diagrams from the Engines with and without Expansion—Results at Astley and Tyldesley—Possible Saving at Collieries in the United Kingdom by the Application of Automatic Expansion Gear.

In all previous chapters dealing with winding machinery (see Volume I) we ventured to lay down some conditions which good winding engines should fulfil, namely, that they should be strong and comparatively light in construction, and more than powerful enough for the maximum amount of work they would be called upon to perform, easy to handle and reverse, even with full pressure of steam on, well within sight of the engineman, easy to start, and easy to stop, and capable of getting to full speed quickly, and such as would allow full power upon the piston at any point of the stroke. Also that they should work in pairs, and be so proportioned that in case of breakdown with one engine the other would be capable of raising the load.

Modern winding engines have succeeded in fulfilling all these conditions in the well-known horizontal direct-acting high pressure non-condensing engine working in pairs, but in doing so engineers have managed to produce an engine having all the virtues except economy. This did not matter so much when pits were not deep, and when the fuel used by the boilers in generating steam

was hardly such as could be sold, and if not consumed in this way would simply go to make ballast or waste-heaps. In latter years circumstances have changed; raising fuel from half-a-mile deep is a serious matter, with all the economy that can be exercised, and as the coal lying so deep must be of considerable value, or it would not be worth while working and drawing it from such a depth, not a pound should be used in the mere expense of raising that can possibly be avoided.

Engines working without expansion and without condensation are the most extravagant class than can be worked. The non-condensation means that with an ordinary winding pressure of, say 60 lb. absolute, nearly one-third exercises no effective power at all, and with non-expansion we throw away twice in each stroke a quantity of unused and full-pressure steam equal to the capacity of the cylinder. There can be little doubt that ere many years have passed away the improvements forcing themselves upon mineowners and mine managers will include the general application of condensing appliances.

The difficulty in the application of expansion gear to winding engines rests in this, that we want full power all through the stroke, and when decking at the top and bottom of the shaft; we want full power to overcome the inertia of all the parts during the first two or three strokes to get up speed as rapidly as possible, and we want unaffected control over the engines throughout the stroke, all through the winding when men are being raised or lowered, and also when a shaft is being examined or needs repair at any particular point, and above all, we must add no gearing to any part of the winding machinery which causes the slightest risk in working. Every person employed underground makes at least two journeys each day by means of the winding engines; and however important economy may be, it must have no place at the expense of safety.

Under these circumstances it is, perhaps, not to be wondered at that so little has been effected hitherto in this direction. It is, perhaps, not exaggeration to say that whilst other engines almost universally have more or less of expansion, scarcely in one per cent. of winding engines has any such arrangement been applied.

Mr. Arthur J. Stevens, of the Uskside Ironworks, Newport, Monmouthshire, has overcome the difficulty by introducing an arrangement known as his automatic expansion valve gear, which in no way affects injuriously the power of the engine or the engineman's control over it, does not lessen the safety, and, what is of paramount importance, produces considerable economy.

This arrangement is illustrated in fig. 12, and with that figure the following description will make the appliance quite clear.

The object of the invention is to produce a simple form of expansion gear, which shall be applicable especially to winding engines, particularly to those fitted with double beat or Cornish valves, and a gear which can easily be applied to existing engines. The object of the improvement is further to produce an expansion gear which shall not require any attention whatever on the part of the engine driver, and which shall be simple in construction, not liable to get out of order, and almost instantaneously put out of gear if required. The gear is of the class known as automatic, and is actuated by an ordinary governor (advantageously one of the high speed class). The gear can be worked by hand, and instantaneously if desired.

Referring to fig. 12, A is the valve spindle of one of the steam valves, B is an ordinary form of lifter, but any other form may be employed if desired. In ordinary non-expansion engines, the lifter, B F, communicates its motion to the bridle, C, or to the valve spindle, A, and the valve spindle follows the motion of the lifter both up and down. In this arrangement the lifter, B F, communicates motion to the bridle, C, through the intervention of the bell crank lever, H G, which is attached to the bridle by means of a pin at D. M is an air dash pot of any convenient form, with an inlet valve, N, and regulating cock, O. Upon the frame, L, which carries the dash pot, are fixed two bearings, P, which carry a small spindle, S, having an eccentric, J, fixed or fitted thereon. The rod R is moved backwards by the governor, and by means of the lever, K, causes the eccentric, J, to make a partial revolution, so that when the governor is full up the throw of the eccentric, J, is in a downward direction.

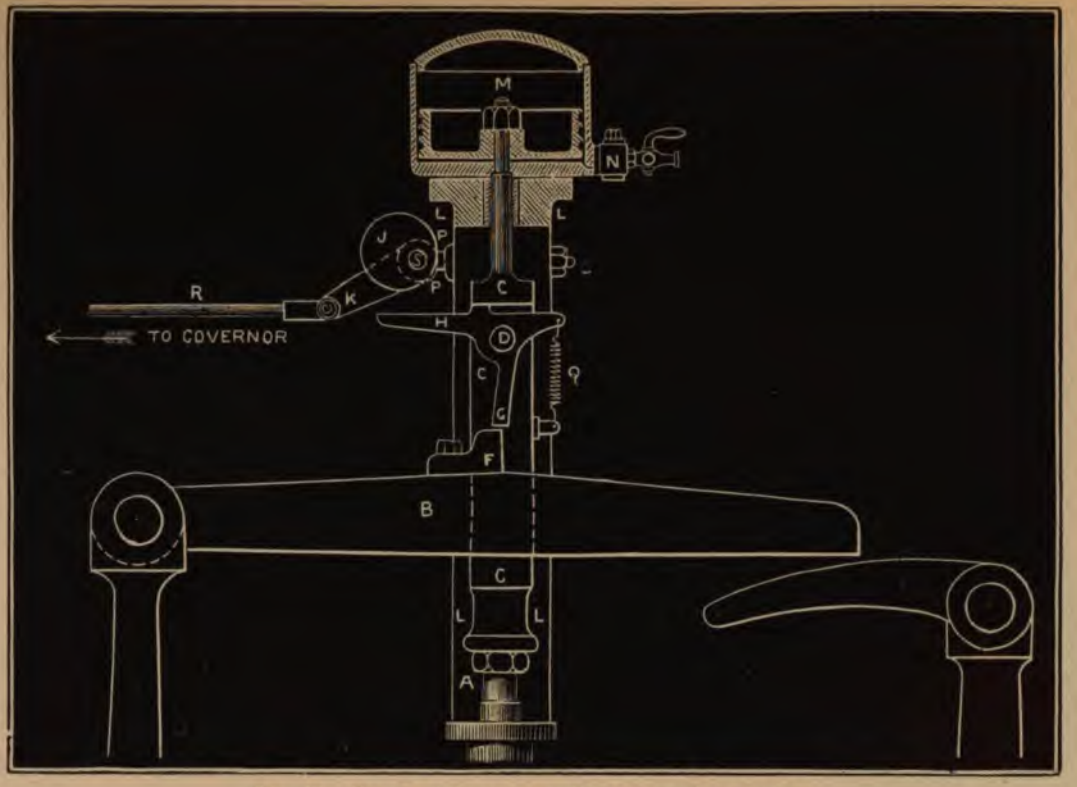


FIG. 12.—STEVENS' AUTOMATIC EXPANSION VALVE GEAR.

To face page 22.]

The action of the gear is as follows:—When the engine is standing or running very slowly all the parts will be in the position shown in fig. 12, and the lifter, B F, will during the whole time be in contact with the bell crank, H G, and the valve will act as though no expansion gear were present, the bell crank, and consequently the bridle and valve spindle following the lifter both in its upward and downward motion. When, however, the engine is running fast, and the governor more or less near its highest position, the eccentric, J, is turned downwards, and as the valve spindle rises the eccentric will come in contact with the bell crank at H, and cause the other end, G, to trip off F, and allow the steam valve to drop, thus cutting off the steam entering the cylinder; the lifter will continue its upward motion unaccompanied by the bridle, and on its descent the spring, Q, will bring the bell crank lever into gear again.

The grade of expansion will thus vary with the position of the governor, and consequently with the speed of the engine. The whole may be taken out of gear by removing the pin which connects the governor, or if the governor be driven by a strap, by throwing off that strap. Such is a description of the appliance, for which are claimed the following advantages:—

1. It is extremely simple, and cannot get out of order, and can, if required, be put out of gear in a few seconds.

2. It is automatic in its action, and gives the engine-driver nothing whatever to do more than an ordinary engine.

3. No expansion takes place at the commencement of the wind, thus allowing the engine to attain full speed as quickly as possible.

4. The expansion is thrown automatically out of gear towards the end of the wind, when the engine is slowed, the driver thus having perfect control over his engine.

5. The gear can be applied without much expense to most existing engines which are fitted with Cornish valves, and at slightly more expense can be applied to winding engines having slide valves.

6. In nearly all other expansion gears the early or late tripping of the valves is dependent upon the versed sine of the arc described by the lifter. Consequently, the

working surface must be extremely small, and must soon wear round. In this gear the width of the lifter may be anything in reason, and consequently if the point does wear slightly round, the only result is that the valve is tripped slightly earlier in the stroke.

The gear was applied immediately on its introduction in 1880 to the Great Western Colliery, near Pontypridd, and has consequently been working there over four years.

The writer has not had the good fortune as yet to visit the Great Western, but Messrs. Brown and Adams, the consulting engineers to the colliery, have been good enough to write that they are much pleased with the automatic expansion gear, and it works very satisfactorily. They also furnish the following particulars:—The winding engines have 40 in. cylinders and 6 ft. stroke; the depth of the pit is 400 yards, the time of winding 35 seconds, the number of revolutions to a winding 21½, the net weight of coal each winding 50 cwt., the gross load, including cage and rope and tubs, 7 tons, and the output in a day of ten hours 1,200 tons.

Fig. 13 gives a diagram just before the gear comes automatically into action, and fig. 14 a diagram immediately after the gear begins to act, and these figures speak for themselves. In the one case we have the communication between the boiler and the piston open all through the stroke, and a very high back pressure during the return stroke, and the other we cut off at one-fourth and reduce the back pressure to a point at which improvement can hardly be effected—namely, barely 3 lbs. per square inch, the work which the engines are doing at the time of these two very different diagrams being as nearly as possible equal. These diagrams are from the winding engines of the Great Western Colliery referred to above. The highest pressure of steam available in the engine-house is about 45 lb.—namely, 60 lb. absolute, and any higher ratio of expansion than four times would cause expansion below the atmospheric line, which would be neither desirable nor practicable in a non-condensing engine. With this pressure of steam cutting off at about one-fourth is as far as expansion can be carried.

Two years ago the gear was applied to a pair of horizontal engines at the collieries of the Astley and Tyldesley

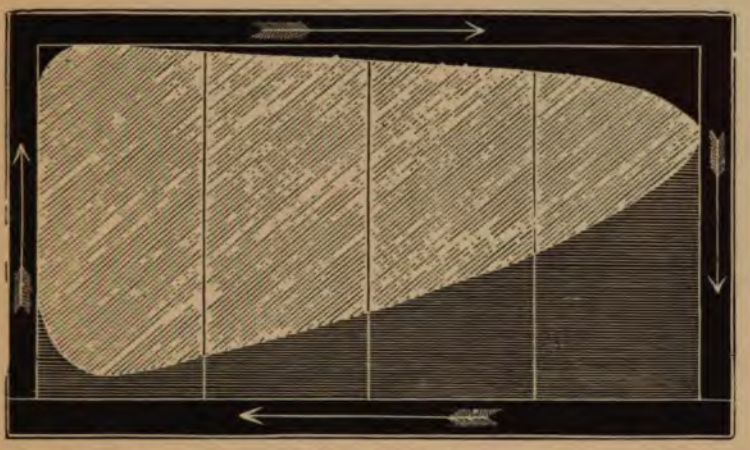


FIG. 13.—DIAGRAM FROM GREAT WESTERN COLLIERY WINDING ENGINES EXPANSION GEAR NOT IN ACTION.

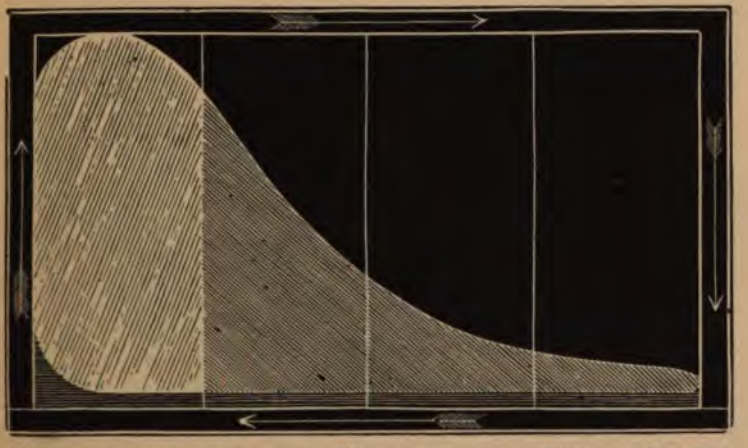


FIG. 14.—DIAGRAM FROM GREAT WESTERN COLLIERY WINDING ENGINES. EXPANSION GEAR IN ACTION.

[*To face Page* 24.]

Coal Company. These engines being within easy reach, the writer has repeatedly visited, and has seen them on many occasions at work, before the expansion gear was applied and since. Mr. G. H. Peace, the manager, who very carefully studied the question of expansion gear for winding engines before adopting this particular plan, has kindly furnished information regarding its application and results. Fig. 15 shows its attachment to these engines. Fig. 16 gives a diagram without the gear. Fig. 17 gives a diagram with the expansion gear in action. The diagrams are not so good as from the Great Western Colliery, but the fault of that is in the engines, and not at all in the expansion gear.

The engines have cylinders 36 in. diameter, and stroke 6 ft., and a cylindrical drum 20 ft. diameter, winding from a depth of 400 yards. The load raised each winding is about 2 tons of coal. The drum being parallel and having a counterbalance rope under the cages, the tubs and cages and winding ropes will exactly balance each other, leaving the actual load 2 tons of coal, and of course the resistances of the machinery. The available pressure of steam in the engine house is 60 lb., and a winding requires a little over nineteen revolutions and occupies 40 seconds. Before the gear was attached the engine worked non-expansively with full steam on during twelve strokes, and the remainder of the journey was performed without steam, a little steam being needed against the piston at the end of the winding. Since the gear was attached two years ago (and it has been working continuously since), the winding occupies the same time and steam is admitted to the cylinders during the same period, namely, about twelve strokes. Sufficient speed is got up and the gear comes automatically into action at the end of the fourth revolution and remains in action during thirteen revolutions, that is till within about two revolutions of the close of the winding. The diagrams show that about the same cut-off is attained as at the Great Western Colliery, namely, at one-fourth.

The gear during its two years' work has given no trouble. The engineman says his engines are easier to handle now than before, and scarcely any noise is made except by the more rapid closing of the valves. The action

of the dash pot breaks what would otherwise be a shock in the closing of the valve.

At the Tyldesley Collieries the gear is worked by a dead weight governor, as shown in fig. 15. The governor is driven by a strap from the drum shaft, the driving pulley being 2 ft. and the governor pulley 4 in. Of course these pulleys can be regulated to anything, just to suit the speed at which the gear is required to come into action. A maximum speed at which the winding engines are desired to run is determined. The pulleys for driving the governor are proportioned so that till this speed is reached the expansion gear shall not begin to operate, and when the speed falls below this shall come out of action.

The results as regards economy are as follow, and very great care was taken to have the engines and boilers working under similar conditions, and thus ensure reliable results :—The boilers which generate steam for these engines generate steam for nothing else, and the output is very regular, being 500 tons per day. Two days were selected, one before the gear was attached and the other after, on which exactly 500 tons were raised, and the engines made the same number of windings. To make the experiment a fair one, two days were selected, one immediately before the application of the gear and the other immediately after, this being a much better test than selecting dates very far asunder. The saving effected was 25 cwt. of fuel for each day, being a reduction of 13½ per cent. This at 5 days per week will amount to 325 tons per year, which at 5s. per ton will represent over £80, an amount by no means to be despised; and with increased outputs and increased depth the saving would be greater. But taking this as an average, the lessening consumption of fuel for generating steam for our winding engines, 13½ per cent., is a result which cannot fail, first of all, to commend, and afterwards to ensure the general application of appliances such as this we have described. Since these experiments were made, and these results arrived at, some better things have been accomplished and still greater economy shown, but what is herein stated is none the worse for being under the mark, and puts in quite a clear enough light the advantages of the gear.

We are probably raising in the United Kingdom at present not less than 600,000 tons of coal per working day, and an economy such as is now obtained at Tyldesley would mean 1,500 tons a day of fuel saved, equal to considerably over a quarter million tons a year for economy in winding engines alone. Nearly £100,000 a year saved to colliery proprietors is worth thinking about.

Mr. Stevens who had previously made his mark by the excellence of his mining machinery, deserves congratulating on having invented an arrangement which, without lessening the safety or efficiency, tends to bring our winding engines within the category of economical steam engines. The writer is pleased to bring under the notice of the mining public an appliance which needs only to be seen to be understood and appreciated.



CHAPTER IV.

COCKSON'S SILENT GUIBAL VENTILATING FAN.

The Defects of the Ordinary Guibal Fan—Advantages claimed for the Cockson Fan—Comparison with the Schiele—Construction of the Fan—The Alexandra Colliery of the Wigan Coal and Iron Company—Ventilation by Furnace—Ventilation by Fan, and Saving effected—Horse-power and Useful Effect—Speed, Quantity of Air, and Water Gauge—Engines for Working the Fan—Method of Communication between Engine and Fan—Rope Gearing—Proportions of Pulleys—Comparison between Straps and Ropes—The Ventilating Plant at the Alexandra Colliery—Mr. Cockson's Efforts in connection with Ventilation.

In concluding Volume I. of *The Mechanical Engineering of Collieries* (see page 212), reference was made to some improvements in ventilators patented by Mr. Charles Cockson, mining engineer, of Wigan, which improvements were intended to combine whatever advantages the Guibal had with the additional advantages of a quick-running and perfectly noiseless fan. One of these improved fans was at that time in course of erection by the Wigan Coal and Iron Company to ventilate their Alexandra Colliery, and a hope was held out to the reader that at some future time information as to actual results would be published in these pages. The fan in question commenced work in July of last year,* and has worked continuously since, and it is thought that the time has now arrived for the fulfilment of the promise made, and to describe the principle of this ventilator and the work it is now doing.

The Guibal, which up to the present time has been rightly or wrongly the most popular of all ventilating machines, is not a silent fan, and its maximum number of revolutions per minute is very limited, and, consequently, to deal with large volumes of air very large diameters are necessary. This causes a three-fold evil. The fan itself is very expensive on account of its great size. The amount

* 1883.

of work required to keep in motion so massive a machine forms a very serious item of the useless resistance to be overcome, and the foundations must necessarily be extensive and expensive. Mr. Cockson claims for his improved fan that it has all the good points of the Guibal as to its ability to produce a given water-gauge at a much less speed than any other type of fan, and, in addition, it has all the good points of the Schiele, being a silent fan, and perfectly free from the vibration which is so objectionable in a quick-running Guibal fan. On this account the improved fan need not be made of the large diameters required for the ordinary Guibal fan, but can be made as light and small as the Schiele, over which it is claimed by the patentee to have the following advantages:—First, that with fans of similar size the new fan will get the same quantity of air and water-gauge as the Schiele at a lower speed; consequently that a less powerful engine will drive the improved fan, and it will be subject to much less wear and tear on account of the lessened speed. Second, that it gives a much higher percentage of useful effect.

The improved fan is of similar construction to the ordinary Guibal, in so far as it has the evasée chimney and the adjustable shutter of that type of fan; but instead of having the blades rectangular, it has the edges so curved as to afford an equal area of air passage throughout the fan, thus avoiding the vibration inseparable from the old type of Guibal. The ordinary Guibal fan cannot avoid the vibration, whilst the improved fan can work at practically any speed, and set up no vibration. The fan erected by the Wigan Coal and Iron Company is 30 ft. in diameter, and was erected to take the place of two ventilating furnaces which produced 142,000 cubic feet of air per minute, and to do so consumed 12 tons 17 cwt. of coal in the twenty-four hours. The fan now working produces the same quantity of air with a consumption of 4 tons 2 cwt. of fuel for the same period. And there is this considerable distinction in the fuel, the furnace used good Arley Mine mixture, whilst the fan consumes common Buzzard slack. The saving in fuel alone is over £3 in twenty-four hours, and the calculation for a year is easily made.

Besides this saving in fuel, the fan, when running at the speed for which it was designed, and of which its capa-

bilities have been proved, produces an increased volume of air of 56 per cent., that is to say, with the fan running at eighty revolutions per minute, the quantity of air is 222,750 cubic feet, with a water-gauge of 4·95 in., as against 142,570 cubic feet of air, the limit obtainable by the furnaces.

The useful effect calculated from the lesser water-gauge in the fan drift is 70 per cent., the indicated horse-power of the engine being 234 and of the air 165. The actual facts and figures are as follows:—Depth of upcast, 240 yards; diameter, 9 ft.; depth of downcast, 255 yards; diameter, 19 ft. It is proposed to make the upcast larger in diameter, but the size was as given when experiments were made.

With two furnaces at the bottom of the upcast, having a combined grate area of 129 square feet, 12 tons 17 cwt. of Arley Mine mixture were burnt in twenty-four hours, and 142,570 cubic feet of air produced per minute. The cost for wages was 19s. 3d., and for fuel £4 3s. 7d., making a total of £5 2s. 10d.

With the fan running at fifty-two revolutions per minute, and burning 4 tons 2 cwt. of rough Buzzard slack per twenty-four hours, 142,197 cubic feet of air were produced per minute, and the cost was for wages, 10s. 6d. per day, and for 4 tons 2 cwt. of Buzzard 15s. 4d., making a total of £1 5s. 10d. Thus we have with furnaces £5 2s. 10d., and with fan £1 5s. 10d., being a difference each twenty-four hours of £3 17s., amounting to a saving under this head of 75 per cent., or considerably over £1,000 a year, which will do something more than pay the interest on money expended.

With the fan running at eighty revolutions per minute it worked quite noiselessly; 222,750 cubic feet of air were obtained per minute with a water gauge of 4·7 in the drift and 4·95 at the fan side next to the engines; and taking the average of 6 diagrams from the engine, the useful effect of the fan calculated upon the smaller of the above water gauges was 70·3 per cent.

The fan is bound to attract great attention in the mining world from the remarkable results attained. Comparatively a small fan, only 30 ft. diameter, producing such a volume of air as 222,000 cubic feet per minute with so

high a water gauge as 4·7 in., and obtaining 70 per cent. of the useful effect of the indicated horse-power of the engine, has not, so far as the writer is aware, been attained by any other fan. And the speed at which the fan can work has scarcely any limit so far as the fan itself is concerned, and depends on the revolutions which the bearings will allow without heating. The motive power is transmitted also in an excellent and somewhat novel manner. About the engines there is nothing remarkable. Horizontal condensing, cutting off at about half stroke, and obtaining about 26 in. vacuum, they work at about five-eighths of the speed of the fan. The connection is made by means of fifteen cotton ropes, each 2 in. diameter, from a pulley 15 ft. diameter on the crank shaft, to a pulley 9 ft. diameter on the fan shaft, so that running at eighty revolutions in the fan we have a piston speed of 288 feet per minute. There is no very essential difference between communicating motion by means of flat pulleys and straps, and grooved pulleys and ropes. In the event of a strap stretching, a lot of slipping is inevitable, and should it break the machine has to stop, whereas with rope gearing one or even two ropes may stretch or even break, and no harm results. On the other hand, we know that ropes and pulleys will probably cost more than straps and pulleys, and it is urged that we have a serious loss to contend with in the friction of the various ropes in their various grooves, and that in this way we shall get a lessened useful effect. If this argument is good, then Mr. Cockson's fan is doing even better than is being claimed. But the writer believes with ropes well made, neither of wire or hemp, but of cotton, working on well-proportioned and well-constructed pulleys, with the ropes nicely fitting the grooves, this method of transmitting motion will render a good account of itself.

The whole arrangement of fan and engines and boilers is excellent, and forms an almost model ventilating plant. And in a short time, when the surroundings are completed, will comprise one of the most interesting sights in the Lancashire coalfield.

Figs. 18, 19, and 20 illustrate the fan and how it is driven, fig. 18 being an elevation from the drift, showing the iron construction of the fan and its chimney.

Fig. 19 is an elevation from the engine side showing the connection between the fan and the engine by means of rope gearing. Fig. 20 shows the fan and its connection with the upcast shaft in plan.

Mr. Cockson's indefatigable efforts to lessen the cost and increase the efficiency of ventilating machines deserve and will obtain substantial success.

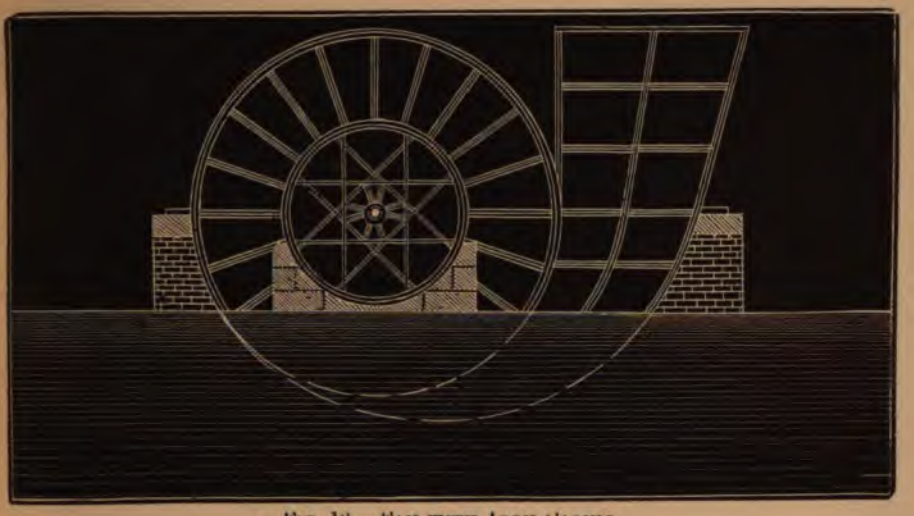


FIG. 18.—FAN WITH IRON CASING.

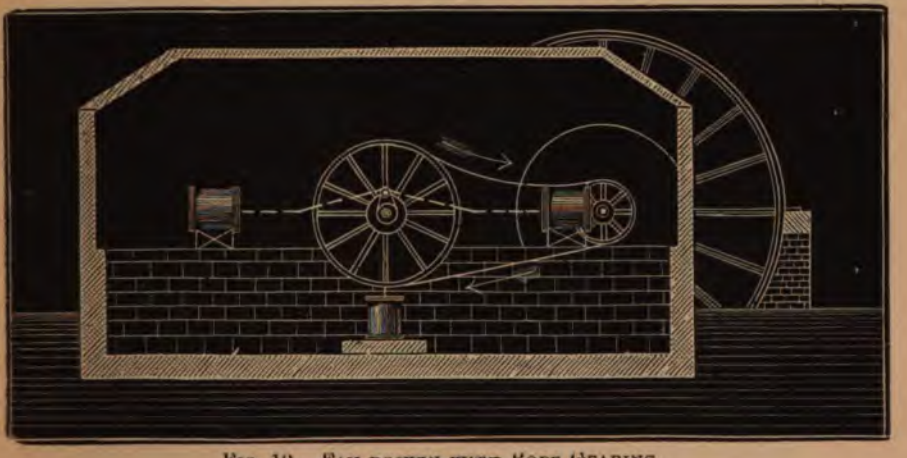


FIG. 19.—FAN DRIVEN WITH ROPE GEARING.

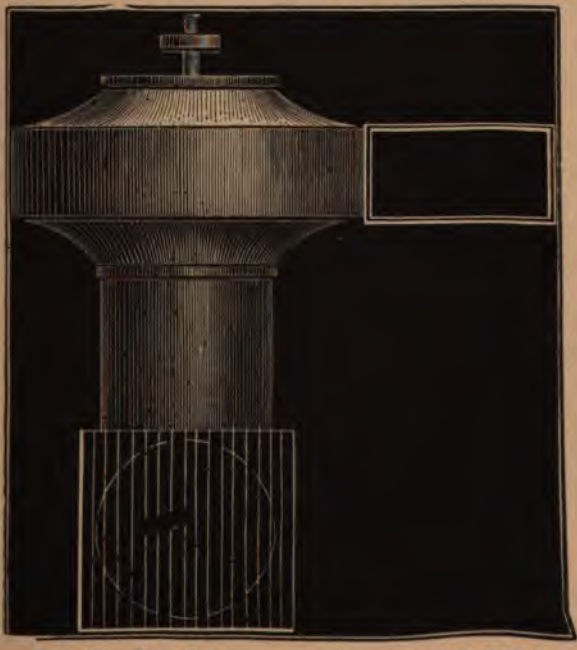


FIG. 20.—FAN PIT, USED FOR VENTILATION ONLY.

[To face page 32.]

CHAPTER V.

THE IMPROVED SELF-REGISTERING SIGNAL INDICATOR.

Indicators needed to show to the Engineman the Position of his Cage in the Shaft—Early Appliances—Gradual Improvements introduced—The Indicator attached to Modern Winding Engines—Objections to Bells in connection with Indicators—The Pepper Mill Brass Foundry Company—The Improved Combined Self-registering Signal Indicator—Its Simplicity and Freedom from Springs, and Non-liability to get out of order—The Position of Load is indicated—The Number of Windings is registered—It shows the Number of Signals that have been given—Can be generally applied to any Style of Engine for Winding or Hauling at Collieries, and for Hoists at Blast Furnaces.

It has always been considered needful, even in very early times, when winding at collieries was so slow an operation that an engineman could occupy his spare time between starting his load from the bottom and raising it to bank by firing up at the boiler, to provide some means of letting the engineman know when his load was nearing the surface, and this was effected in many cases by having a mark upon the winding rope, which coming above the surface gave warning that the load was approaching. This was a rude method, and only told when the load was near the bank, giving no information at any other time in what part of the shaft the load might happen to be; but for the old times, with shallow pits, small load and engines, and slow speeds, it answered well enough.

As the coal trade developed, depths increasing, loads becoming greater, and speeds higher, a less rude appliance became necessary, and a considerable improvement was thought to have been introduced by having a pin on the end of the crank shaft or drum shaft, and a string which coiled round the pin, raised or lowered a weight during

each winding, and a bell was caused to ring when this weight reached a certain point. This did well enough if the appliance kept right, but the string had a tendency to coil irregularly, or the wetness and dryness of the string shortened or lengthened it, so that it could not be considered a very reliable guide.

As improvements advanced, instead of simply raising and lowering a weight, a model arrangement of the cages was adopted, especially when the engineman had no view of the actual cages, by which the position of each cage was shown at all times during a winding.

This arrangement has been made very complete latterly by dispensing with the pin upon the shaft end, working the appliance by wheel and worm gearing, and having the rising and falling weights or cages moving on screws, thus compelling absolutely accurate movements.

The necessity for a really good arrangement cannot now be over-estimated. Time with winding operations is money. At many important collieries the whole time of winding and banking does not cover over one minute, the average speed of the cage will be thirty miles an hour, and the maximum speed exceeds that of many mail trains. An engineman has no time for hesitation or consideration; he has quite enough in starting and stopping his machinery, and the periods for doing so should be made absolutely clear by a correct and almost infallible mechanical arrangement.

By far the most popular arrangement is that having a dial somewhat similar to a clock face, on which the revolutions are marked in plain figures, and a finger moves round, first in one direction and then in the other, according to which cage is being raised. There scarcely can be a better arrangement than this. It forms a neat and even ornamental feature of a winding engine house, can be made absolutely correct, and with proper material properly fitted will go on without giving any trouble or causing any mistakes as long as a colliery lasts.

The ordinary indicator, as has been remarked, has the various revolutions shown upon the dial, and the finger when within two or three revolutions of the end of the journey strikes a bell as a warning to the engineman's ears that his cage is near the top. It is not universally

believed that this bell is a safeguard, some authorities even go so far as to consider it a danger, and have removed it.

No engineman should rely entirely upon this bell, because for different engines its position might not be exactly the same. In one case where an engine has no balancing arrangement, steam is shut off when little more than half the journey has been made, whereas in other cases an engine well-balanced runs with steam on very nearly to the top. An engineman must be guided by his sight and by the speed at which his engine is running, because a few pounds more or less of steam make a considerable difference in the speed of an engine.

The writer does not think the bells an absolute essential to safety, but he considers them an additional safeguard, and they certainly tend to expedite the winding, and thinks they should be universally, as they are very generally, adopted.

One danger in their not being universally adopted is that an engineman having been used to them at one colliery goes to another where they are not in use, and perhaps an accident results. On the other hand, opponents say an engineman gets accustomed to them, cannot do without them, the bell gets out of order, and the engineman waits for a signal which is never given, and the consequence is an accident.

The answer to this is: There is no excuse for such appliances getting out of order anywhere, but at a colliery, where all arrangements receive, or should receive an inspection daily, this inspection, if not a mere sham, will certainly prevent such an important piece of mechanism as an indicator going wrong. The balance of opinion and of advantage is much in favour of the bell.

But it has long been the writer's opinion that indicators should do more than this, and in Vol. I. in the chapters on winding engines he ventured to suggest some other results that should be obtained by means of these appliances.

Somewhat singularly, at an exhibition of engineering appliances held in the Wigan Mining and Mechanical School, a firm eminent in colliery work, namely, the

Pepper Mill Brass Foundry Company, of Wigan, whose indicators are not only all over England, but largely used abroad, exhibited a new form of indicator, which accomplishes what the best indicators have hitherto done—all that the writer ventured to think two years ago was desirable—and something beyond, and well deserves its name—*the improved combined colliery self-registering signal indicator*. It was a pleasure which the writer gave himself during that exhibition to explain to such of the students of the institution in whose buildings the exhibition was held as visited it the principles of some of the exhibits, as an encouragement to them in after years to combine their theoretic knowledge with practical experience, and benefit mankind by productions of their genius; and the writer thinks such explanation as was offered to students may do no harm to his more numerous body of friends.

The accompanying figure 21 well illustrates the improved form of indicator. It combines in one neat structure the ordinary winding engine indicator and the signal bell, thus making unnecessary two separate fixings in separate parts of the engine house. The advantage is that the attention of the engineman is concentrated on one point only, thus simplifying his work and avoiding possible confusion, which confusion too often is a source of accident. The arrangement is as simple in construction as such an appliance well can be, and its freedom from springs, depending for its action on weights, removes the liability to get out of order, which makes indicators in many cases an actual source of danger.

This interesting combination of mechanism performs three distinct duties—

1. The large dial indicates the position of the load in the shaft. A gong or bell is struck when it is necessary that the engineman should be in a position to check his engine. The point at which the signal is given may be fixed at three or any number of revolutions from the top, according as the engine is of such a character as needs checking soon or late in the winding.

2. The small dial in the inner circle of the large one indicates and registers the number of windings. This is important as giving the actual work done in each day,

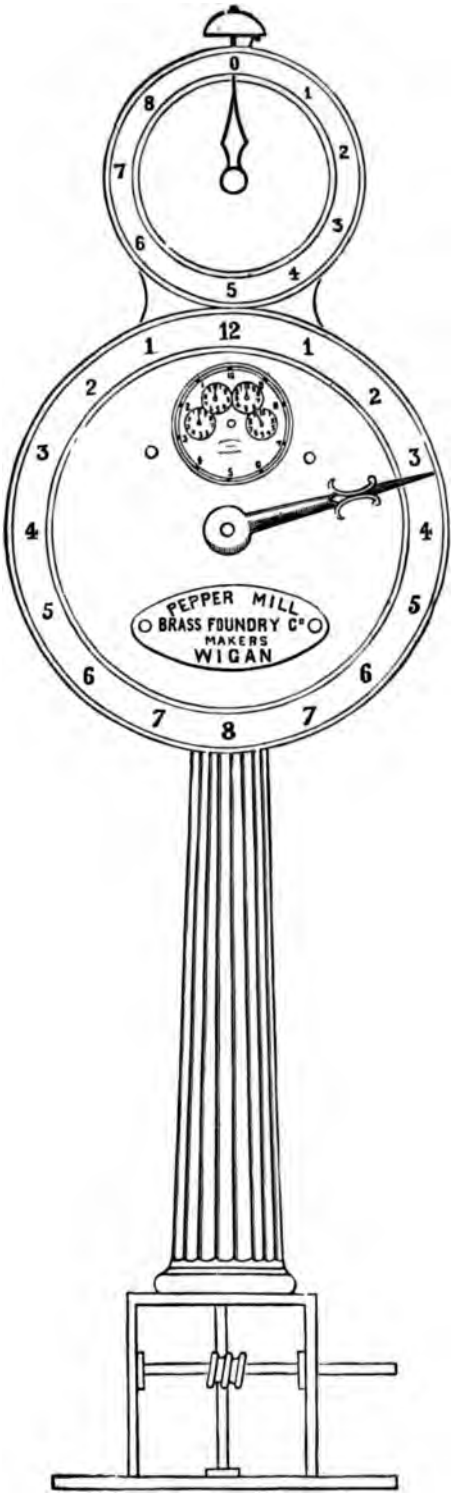


FIG. 21.—IMPROVED COMBINED COLLIERY SELF-REGISTERING SIGNAL INDICATOR.

[*To face page* 86.]

and also furnishes information as to what a winding rope actually does during its lifetime. The work done by a rope is not exactly represented by the number of months or years it works, nor even by the mere weight of coals raised, but more accurately by the number of windings it makes. In some cases such an arrangement has been spoken of somewhat lightly, because it has been tampered with, but provision can easily be made against tampering by enclosing the mechanism in a locked case. And if this is a fatal objection we should be practically without appliances, as nearly any mechanism is capable of being tampered with.

3. The top dial indicates the nature and number of signals given from the bottom of the shaft, the object being to enable the winder in case of doubt to ascertain by the aid of this dial the actual number of signals given. The finger on this dial moves simultaneously with every stroke on the upper bell, and points to the number corresponding to the number of signals, and remains in that position till the engine moves, after which it returns to its normal vertical position.

Such is the *improved self-registering signal indicator*, than which it would not be easy to introduce a more efficient and essential appliance, or one less liable to get deranged. It can readily be attached to any style of engine, and must prove extremely useful, not only for winding engines, but also for hauling engines and hoists at blast furnaces. Although a new contrivance, it has been well received, and only needs to be widely known to be very generally applied.

CHAPTER VI.

AN ARRANGEMENT OF MECHANICAL SCREENING.

Brooks and Pickup's Collieries, Burnley—Waddell Fan—Bailey's Fan Recorder — Counterbalance Chains — Endless Chains — Fisher's Method of Loading and Unloading Colliery Cages—The Mechanical Engineers in Belgium—The Mariemont Collieries — M. Guinotte — Automatic Machinery for Hauling, Emptying and Classifying Coal, Loading it on Trucks, and for Cleaning—M. Briart—Results of Hand Screening and Mechanical Screening Compared—Mr. Landless—His Mechanical Screen at Burnley—Defects of all Fixed Screens—Construction of the Burnley Screen—Method of Working—Amount of Coals that can be dealt with—Effective Separation of Round and Small, and Freedom from Breakage—The Arrangements at Mariemont, in Belgium, evidently copied from the Landless Screen at Burnley.

During a visit made to a Lancashire colliery a year or two ago, the writer's attention was drawn for a few moments to a screen in which the bars were alternately fixed and movable, but being engaged at the time chiefly with other matters, little notice was taken, and no notes recorded. The colliery in question belonged then and belongs still to Messrs. Brooks and Pickup, of Burnley, and the visit was made by invitation of the late Mr. Pickup, to see the action of Bailey's Recorder in connection with a Waddell Fan (described and illustrated in the first volume of this work); also counterbalance chains working well under cages in a case where counterbalance ropes had not done so well, and to see the principle of endless chain-haulage worked out almost to perfection. Endless chains did all the haulage above ground and below, almost took the loaded tubs from the cage, conveyed them to the screens, and returned them when empty to the cage, and an endless band carried all the coke from the mouth of the ovens into the wagons. It occurred to the writer whilst watching some time afterwards at Clifton

Colliery, Nottingham, Mr. Henry Fisher's excellent and ingenious self-acting arrangement for loading and unloading cages, that if such an appliance were introduced at some of the Burnley Collieries, the banksmen would have absolutely nothing to do. Amidst so much that was excellent it was not to be wondered at that so simple a matter as a screen almost escaped notice, and certainly this article would not have been written but for a somewhat peculiar incident. In July of 1883 the English Institute of Mechanical Engineers visited their brethren in Belgium, and a very happy and instructive few days were spent. Unfortunately, being somewhat limited for time, and anxious to devote some time in Belgium away from works and collieries, the writer did not form one of the party to the celebrated Mariemont Collieries, which seem to be considered on every hand about the finest and best equipped for their appliances of all the collieries in Belgium. On his return to England the writer was consulted about some proposed improvements in screening arrangement, and his attention directed to the following notes extracted from a description of the Mariemont Collieries, prepared under the direction of the managing director, Mons. Guinotte. These notes were printed previous to the meeting and distributed by the Institute amongst the members, and afterwards appeared more or less fully in all the English and Continental mining and engineering journals.

The establishment of an automatic system of hauling compelled the installation of a complete plant for emptying and classifying the coal, and for loading it on trucks, giving it at the same time a thorough cleaning.

Classifying has been carried out by the employment of screens with movable gratings, invented by M. Briart. Every system of screening must satisfy the following main conditions:—

(1.) The different classes of coal must be completely separated.

(2.) The coal must be preserved from breakage.

(3.) The work must be rapid and cheap.

Ordinary fixed screens placed at an angle may satisfy some of these conditions, but not all. If the angle is small, the coal does not break, but the separation requires

a considerable amount of manual labour. The work is also slow, and the screens, if the output is large, must be very numerous. If the angle is high, the coal falls more rapidly, but it thus gets broken, and the proportion of large coal and rough slack is diminished. Moreover, the separation is imperfect.

Various systems have been invented to overcome these difficulties. In England and Germany cylindrical screens are largely employed. They work well as to separation and rapidity, but if the coal is friable the breakage is large. M. Briart has adopted another principle, which prevents any breakage, whilst effecting the complete separation of the different classes and largely diminishing the manual labour. The apparatus consists of one or more gratings placed one above the other, and working in the same way. Each is formed by a row of fixed bars and a row of movable bars, which, when at rest, lie in the same place. The movable bars are fixed in a frame, which at its lower extremity is carried on two cranks, and at its upper extremity on two eccentrics keyed on a rotating shaft. The movable bars are above the fixed bars during one semi-revolution, and below it during the other. During the former, they have a longitudinal motion down-hill, during the latter, a similar motion up-hill. Hence, when a coal wagon is emptied upon the upper part of the screen, the coal is first lifted by the movable bars and carried downwards; it then rests on the fixed bars during the lower semi-revolution. At each revolution the coal is thus shaken up throughout its mass and gradually screened. All the small coal falls through the spaces between the bars, whilst the large coal is brought to the bottom without any shock, by a succession of steps. If necessary, both sets of bars can be made movable.

If there are to be three classes of coal, two screens will be required. The first separates the large coal from the rough slack; the latter, which falls through, is received upon a frame, which carries it upwards to the top of the lower screen, and on this it is separated into rough slack and fine slack. This lower screen may be placed horizontally, which enables the height of the discharging road above the rails of the delivery road to be lessened. This height has been fixed at 6 metres (19·7 ft.)

Experiments made on coal screened by the old and the new method have given the following results :—

	Mechanical screening. Per cent.		Hand screening. Per cent.
Large coal.....	16·35	.....	13·15
Rough slack	32·63	.....	31·08
Together	48·98	.....	44·23
Fine slack	51·02	.....	55·77
Total	100·00		100·00

In the more recent examples, by simply turning a handle, without stopping the apparatus, it is possible to vary the distance between the bars of the screens, so as to alter the character of the screening. There are also mechanical means for cleaning the coal and for transferring the screened coal into wagons without falling from any height. The yield is thus increased and the manual labour much diminished.

Such was the information, without illustrations, placed at the disposal of the English visitors by the Belgian authorities. So far as the effect upon the slack is concerned, reducing the percentage of fine slack from something over 55 to something over 51, and increasing the rough slack about 1 to 5 per cent., there is not much in that. A really good screening arrangement would probably show a higher proportion of slack than a less efficient one, for the simple reason that in bad screens a fairly large amount of slack finds its way into the coal wagon, whilst a really good screen puts all the slack, however much it may be, in the slack wagon.

The writer at once remembered having seen at Burnley, at the collieries of Brooks and Pickup, an arrangement of screen of which the above forms a very fair description, and such screen was introduced by a Mr. Landless, then the engineer at the colliery, and now an engineer in practice at Burnley, and this screen is fairly well shown in the figures accompanying this article. Probably the publication of this article may be the means of ascertaining whether the appliance was ever patented, or whether at any other colliery this particular screen was adopted. The

writer has no information upon either point, but believes this may be classed amongst the useful contrivances which colliery engineers in pursuing their ordinary avocations apply at some particular place to overcome some special difficulty, and nothing is heard of them beyond their own immediate precincts. The special objects of this mechanical screening are to ensure an effective separation of the round and small, and a uniform descent of the round coal down the screen towards the wagon. With the ordinary fixed screen, as described in Volume I., a considerable inclination is required (which may be taken at 1 vertical to 2 horizontal) to induce the coal to descend by gravitation, and to have anything approaching a reasonable screening length there must be a good drop from the tippler to the wagon. The result is that if unimpeded the coal rushes down with increasing velocity, and where its movement should be easiest, namely, on leaving the screen, it possesses the most force. For hard coal, not easily injured, this sort of thing may do well enough, but for tender coal it simply will not answer at all; the screening is ineffective, and probably more slack is made by dashing into the wagon than is taken out on passing along the screen. And with a fixed screen if we break the fall by having doors at certain points, and assist the screening by raking the coal well over the bars, this sort of intermittent screening, dealing, or trying to deal, with a comparatively large quantity at one point gives, as experience shows, inferior results, and reduces very much the amount with which a screen can deal.

Fig. 22 gives a side elevation of the arrangement; fig. 23, a longitudinal section; and fig. 24, a plan, which, roughly described, has its principle of arrangement somewhat as follows:—The screen is constructed as is usually the case, with bars about 4 ft. long, or any other convenient length; that at Burnley is in five lengths, but such a length of screen, amounting to upwards of 20 ft., is unusual. The fixed portion of the screen is a cast-iron frame (see figs. 25, 26, 27, 28) resting by means of feet upon timber bearers crossing under the screen from side to side, the bars being made wedge-shaped so as to allow the small coal to pass freely away. Probably a much better section of bar than this, having a broad flat upper surface,

ERRATA.—Fig. 26 should be described as "End elevation of fixed portion of Screen," and Fig. 27 as "Section of fixed portion of Screen."



will suggest itself to the general reader, and, indeed, has been described in Volume I.; but that, and even the actual construction generally are mere matters of detail, not affecting the principle of the arrangement. The movable portion of the screen (see figs. 29, 30) is also a frame resting at the lower end upon a lever at each side, and connected at the higher end to cranks, which have a throw of 4 or 5 in., and, as a consequence, while the upper end has a vertical movement of 5 in. and a horizontal movement of 5 in., the lower end simply has a longitudinal movement of that extent. The action of this screen is that the alternate bars having this rising and falling combined with oscillating movement, the fuel is raised and carried forward during the upward arc, and being deposited again rests during the lower arc. By this means scarcely any inclination of screen is needed; in fact, as has been proved by the application of almost the same principle in another way, it will work if absolutely horizontal. In one of the most efficient of the many smoke prevention arrangements, the leading feature is alternate movable bars. But whether slightly inclined or perfectly horizontal, the coal is dealt with most tenderly, the screening is uniform and effective, and as the screening is performed mechanically the hands in attendance can devote themselves to picking and removing the dirt. There must necessarily be a gap at the end of one and beginning of another set of bars, and this is covered by a plate as shown, which moves freely under the movement of the bars, yet all the while covers the gap.

The amount of fuel which can pass over a fixed screen depends, of course, upon the amount of small and dirt, but for average fuel 200 tons in a working day may be considered a reasonable quantity, and some slack is necessarily, however well the bars be constructed, carried into the wagon. Picking whilst screening on an ordinary screen is scarcely practicable, the rapid descent and considerable fall dash the coal to pieces, and picking in the wagon makes slack by trampling. With tender coal, passing over fixed screens, the purchaser often finds, to his annoyance, a considerable proportion of slack, which is partly carried over the bars, and partly formed in the wagon. At Burnley,

the screen, instead of an inclination of 1 in 2, is only inclined about 1 in 4, and might, as has already been pointed out, be nearly level. The length of screen bars is about 20 ft., and may be less or more as circumstances require. The movable bars of the various ranges usually act simultaneously, but any one or more ranges may be at work whilst other ranges are at rest to allow picking. This simultaneous action is advantageous, inasmuch as it avoids an ugly gap which would otherwise be necessitated at the end of one range of bars and commencement of another. Motion is communicated to the bars by bevel gearing, as shown upon the plan (fig. 24), and the usual speed is about forty revolutions per minute. In the event, which is usual, of all the ranges of bars working together, there would be some liability to irregularity in the movement of the machinery, because a great deal of work would be entailed in the upward stroke of the small cranks by having to raise the whole weight of the bars and the whole weight of coals, which might and probably would be many tons, resting upon them; and in the downward stroke the machinery would incline to run away. To remedy this it occurred to the writer that if the cranks of the various ranges of bars were fixed at correct angles to each other there would be a perfectly balanced arrangement. But the difficulty this raises is twofold. First, we should have to contend with an awkward gap between each two ranges, and this gap would vary in extent; second, in the event of any one range being made stationary, that is, thrown out of gear, and the others continued to work, the system as far as balancing is concerned would become disorganised.

There seems no better method than that in actual use at Burnley, namely, to continue the crank shaft a little way and put a sufficient balance weight on the side of the screen opposite from that on which the bevel gearing works. In this way we can have a correctly balanced arrangement, and each range is complete and perfect in itself. Considerably over a thousand tons have been effectively dealt with over this screen in a working day, the fuel being thoroughly screened and passed into the wagon easily, avoiding breakage.

No doubt this particular colliery is fortunate in its coal, which is not only rich in quality, but very free from dirt, and hence the large amount which one screen with two ordinary tipplers will deal with. It is not suggested that such an arrangement would deal with such a large quantity at the great majority of collieries, where unfortunately more dirt comes along with the coal; but it is suggested that this system of mechanical screening will deal more effectively as regards slack and dirt than any mere fixed screen, and will for any quality of coal do better work with half the number of screens, with the very special advantage that high stages are not essential, but the system can be adapted to any stage, whether high or low.

There is no doubt in the writer's mind that the appliances at the Mariemont collieries, both as regards haulage and screening, have been not exactly copied, because they are more elaborate and embody improvements, but certainly taken from the Burnley Collieries, as anyone comparing the description which commences this article with these illustrations may judge, especially when one little fact is added—that the Burnley screen has been working seven years; the Mariemont appliances are quite new, and two or three years ago some Belgian engineers took careful notes of the Burnley screens. And no Continental engineer has ever taken nearly so much interest in English mining appliances as M. Briart, who, whilst one of the engineers at Mariemont, where he is now a director, translated into French in 1871 the *Report on Haulage*, prepared a few years before by the Committee of the North of England Institute.

No one is more ready than the writer to give full credit to the Belgians for what they have done in such important matters of mining as the improvement of safety lamps and the introduction and development of machines for ventilation; but in matters of haulage, as we hope to show hereafter, and of screening, as in this article we have tried to prove, Lancashire has led the van.

The Mariemont authorities have most courteously placed at the writer's disposal drawings which, although not nearly so clear as readers would desire, will probably afford at some future time useful facts and instructive sketches. Meanwhile, at a time when the necessity for increasing

efficiency and reducing breakage in screening of coal had given prominence to the excellent equipment of a colliery abroad, it cannot be considered out of place to have shown that as good a system as could well be desired was introduced so modestly as to attract little attention seven years ago, and although during all that time doing excellent work, is still practically unknown.

To Mr. Landless, of Burnley, of whom the writer knows nothing except through this appliance, belongs the credit of having introduced a screening arrangement which has not only done good work at home, but has received the high compliment of being made the foundation of an elaborate system at one of the best equipped collieries on the Continent.

CHAPTER VII.

PUMPING ENGINES AND APPLIANCES.

Introductory.

Comparison between Pumping and Winding Water—Arrangements when Water is wound—Tank swung below the Cage—Teeming Appliances—Pumping Engines should be equal to Double the Probable Work—Lodge Room should be provided—Pumping Engines on the Surface and Underground—Height and Number of Lifts—Height of Suction—The Siphon, its Use—Effective and Defective Construction of Siphon—The Principle of the Siphon—Conditions under which a Siphon will and will not act—Illustrations of the Application of the Siphon and of the Inertia of Water in Pipes—Theoretic Velocity from a Siphon.

In reviewing a work on pumping machinery, a leading engineering journal* suggested that there was room for some one to write a treatise which should deal with pumping engines generally, in the same manner as James Watt had done specially with the Cornish pumping engine. The writer of these articles scarcely undertakes so ambitious a project, but proposes modestly to attempt the production of some comprehensive and instructive remarks. The subject of pumping is a very large one now, and comprises very many types of engines and valves, and very many different kinds of arrangements. All these cannot even be touched upon, but it may be possible, by selecting some representative systems, to offer some fairly interesting particulars.

It is proposed first of all, to mention some general considerations which should guide us in determining and fixing pumping plant; then to offer an historical sketch giving the early efforts in pumping machinery which have led up to our present magnificent and effective appliances; afterwards to describe some of the better known and more extensively used pumping machinery of our own time.

* *The Engineer.*

During the period in which these articles have been passing through the press incidental mention has been made from time to time of collieries with no water at all to pump, such as Abram; other collieries where pumping water can be made not only no expense, but an actual profit, such as Collins Green, and others again, such as Burnley, where, at an enormous expense, considerably more weight of water has to be raised each twenty-four hours than coal. In the latter case the very existence of the concern, commercially, often depends on the efficiency and economy of the pumping machinery. Sometimes, in opening out a new colliery, it is known to a sufficient nicety the quantity of water which will be met with, and the depth. In such cases arrangements can be made from the beginning for dealing with it, and the expense of experiment and change avoided. In other cases the coal proprietor is not so fortunate; he, perhaps, anticipates a moderate supply of water, or scarcely any at all, and gets a great deal. Others, shall we say more fortunate, expect and prepare for a considerable quantity, and find not a great deal. Accordingly, the machinery that has been got ready is not needed, and expensive pumping plant is thrown upon their hands. This may be a little annoying, the incurring needless expense, but after all the ultimate cost is less.

The first point for consideration is, shall such water as may be reached be pumped or wound? Some mining people are of opinion that winding is as cheap as pumping, and, even for very large quantities, will advise winding. If the quantity of water is not great, and the pit deep, then it is hardly worth while to put down expensive pumping plant, especially if the winding engines have abundant time to cope with it. But there can be no comparison as to the cost of actually raising the water. Winding engines are, as made at present, not usually economical engines; they work without condensing arrangements, and, in most cases practically non-expansively, and they are intermittent in working. Pumping engines can be made with all the best appliances for expansion and condensation, and work continuously, that is, at least, for a considerable time at once. Winding ropes are liable to receive a good deal of injury in wind-

ing water, not so much from the weight raised, because the strain is no greater with a ton of water than with a ton of coals. But the injury is from wetness of shaft. Some water gets out of the tank during winding and falls down the shaft whilst teeming, and scatters itself all over the shaft, doing injury to ropes, conductors and even the shaft itself. There is another grievous cause of damage in water winding. The connection between rope and cage is rigid at the capping, and as has been stated in previous articles, this part of the appliance, if the capping is well made, will do no injury, and unless there is something unusual in the working a good capping will wear as long as a rope. But the capping is rigid, whilst the rope is flexible. The letting of the cage or tank or both into the water allows some slack to collect, and this causing repeated bending just above the capping is liable to first injure and ultimately produce breakage. And in any case re-capping has to be more frequent. A partial remedy for this is to dip the cage gently into the water, and it would appear that to do this effectually and always preserve tightness in the winding rope, the tank placed below the cage should have its under side shaped to allow it to enter the water easily. The cost of pumping is less and the injury to winding machinery and shaft is less than in winding, and besides, winding machinery is more profitably employed devoted to its own proper work—namely, raising coals and raising and lowering workpeople. But, as already mentioned, water winding is in favour with some reason at various collieries, and in such cases the greatest care should be exercised in the operation. Sometimes a tank is placed in the cage—and this is the steadiest arrangement—but if much depth has to be got out it causes inconvenience at the surface if there is not height in the headgear, and the descending cage receives considerable injury by repeatedly being dashed into the water. On the whole, a better plan is to suspend a tank below the cage (see fig. 31) adapting the length of suspending rods to particular circumstances. These tanks should be well secured to cage bottom by plates running the whole length or width of cage, and the tanks are usually made of iron, with one clack in the bottom for filling and another on one side for emptying

(see fig. 31, representing elevation, and fig. 32, representing plan). Provided the lower clack is fairly large, proportionate to size of bottom, the tank will enter the water without much oscillation, but some shaking is unavoidable on leaving the water. An attendant at the pit bottom is essential—not so much for steadying the cage and tank when they have left the water, because the engineman can accomplish that—but to see that the bottom clack is closed. At times a bit of wood or dirt prevents this closing, and if sent up the pit part open the tank will empty itself during the winding. No attendant at the surface is needed, a fixed stud acting upon a lever can make the clack in the side automatic in its action. Usually the tank is open at the top, but it would be better to provide a lid to prevent the water dashing over the sides. The weight of water raised each winding will, of course, in a large measure be dependent on the total quantity to be raised. It should always be remembered that the winding ropes are usually proportioned to the weight of coals, and in winding water the load should not be greater than in winding coals. The arrangements at the surface should comprise a trough, a settling place and pipe or drain, all so arranged that the water when wound does actually pass away and does not find its way down the shaft again. (See fig. 33.) It is not only that water finding its way back into the pit represents so much work to be done over again, and damages the shaft, but it undermines the foundations of the headgear. It is useless putting in a firm foundation, and exercising care in fixing a headgear, if water is allowed to work itself about the feet, spoiling the foundation, and rotting away the main posts.

In sinking, unless the amount of water is very great, it will be dealt with in hoppits, and sinking go on at the same time. At some of the North Stafford collieries the hoppit or barrel used for winding this water whilst sinking had only one clack, namely, in the bottom. After being wound to the surface, and the jiddy run under, the dropping of the water barrel upon the jiddy opened this clack and discharged the water. But this, always an unpleasant method for the workmen, and retarding operations, becomes impossible with large quantities, and either



FIG. 31.—TANK SWUNG BELOW CAGE.

[*To face page* 50.]



FIG. 32.—PLAN OF TANK SHOWING CLACK IN BOTTOM.

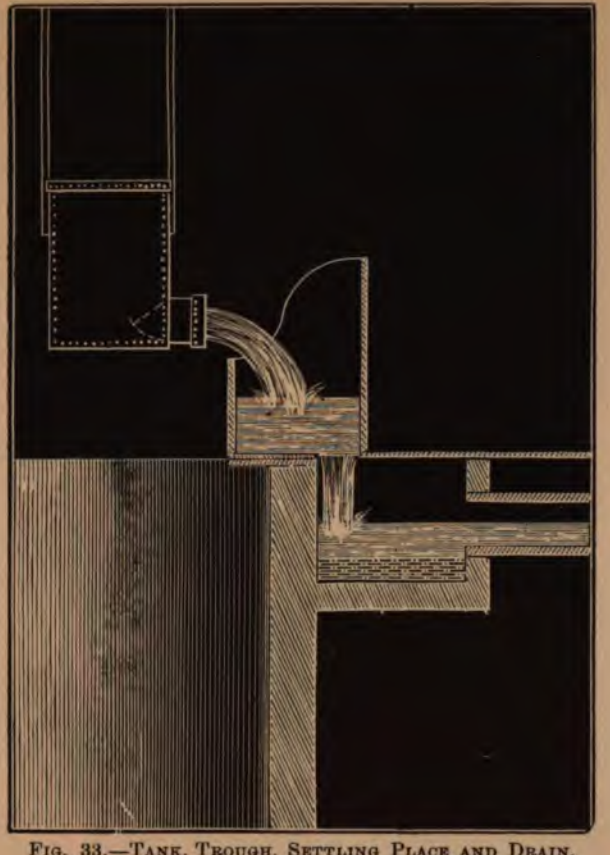


FIG. 33.—TANK, TROUGH, SETTLING PLACE AND DRAIN.

we must suspend a pump in the shaft and lower it as the pit increases in depth, or, what is better, have a running lift, with the engine placed on the surface. The pump itself, that is, the foot of it, will slide out to adapt itself to increased depth, and draw up out of the way to some extent when shots are being fired.

But just at present we are supposing shafts down, and quantity of water ascertained. How should we be guided in dealing with pumping arrangements? If the quantity of water is very great and space can be hardly provided for an engine sufficiently large underground, and if the mine is such that steam cannot well be generated underground, or even taken down in pipes, then the engine must be fixed upon the surface. Some readers will say if the only difficulty is as to steam underground, use compressed air. The writer has not a great deal of love for compressed air. It is all very well for small engines for pumping small quantities, and which have to be placed here and there and everywhere in the mine. But where large power is required, compressed air, to say the least of it, tends not in the direction of economy. Specially made and specially expensive engines have to be provided simply for compressing the air, and then all the other machinery has to be provided just as if there were no air-compressing engines; and the useful effect is so low. Theoretically, its maximum is 50 per cent., and practically, probably the average useful effect of all the air-compressing engines at all the collieries does not exceed 25 per cent. In the face of this, no wonder that only in exceptional cases are air-compressing engines used. This objection to compressed air does not apply if the profits that can be realised from working a colliery will afford the expense. But when the margin, where there is one, is small indeed, the use of compressed air will probably turn the balance the wrong way. Whether the engine is placed above ground or below, it should be equal to its work. And what is equal to its work in a pumping engine? The engine should be equal to double the highest quantity of work it can ever be called upon to do, that is, it should be capable of pumping in twelve hours the water made in twenty-four hours. Not necessarily work twelve hours, and be idle twelve hours, because if circumstances

allow it is a good thing to keep an engine nearly constantly at work. If this is so it can work below its maximum speed. In many cases the pumping engine will only work at night and the winding engines only in the day, thus avoiding the necessity of a double staff of boilers. But in any case the pumping engine should be equal to twice its work. Then as to storage of water. It is too frequent a practice that scarcely any lodge room is provided, and should a stoppage of the pump extend over twenty-four hours the mine is flooded, doing injury, causing risk, and entailing expense. Either in the sump hole or in a specially made lodge, or in both, room should be provided for a week's make of water. Then if the pumping engine and appliances break, or if they need repairs without breaking, abundance of time is afforded for putting matters to rights without injury, risk, or special expense. Water may be found in considerable quantities at various mines in the same pit, and if so it is unworkmanlike to convey all to the lowest point for the purpose of concentration. Fix a pump or lift and provide storage room at each of these points.

When the engine is placed upon the surface there will be several lifts in either of two cases. If the depth is great probably no one lift will exceed 100 to 150 yards, and the water be raised at two or three times, as the case may be, and if all the water is made or collected at the bottom, the various pumps will agree in size. But if the water is made and collected at several points, then the various pumps will increase in size from the bottom, because each upper pump has to deal with its water and the water lifted to it.

When space can be provided below ground, and when steam can be applied there, the pumping engine will in most cases be fixed in the mine. The steam may be generated in boilers also fixed underground, and in such a case the engine will work under conditions highly favourable to economy, namely, the engine close to the pump without the intervention of rods, and the boilers close to the engine without a long range of pipes between. Mining engineers are not favourable to boilers underground, and although possible and safe enough in some cases, there are others where disastrous accidents have been caused by them. Or

the steam may be conveyed in pipes down the shaft, and with condensing arrangements, as many pumping engines now have, will cause no injurious exhaust. Such steam pipes in the shaft, if economy is considered, should be well protected, and not, as is done sometimes, allow steam leaving boilers at the surface at 60 lb. to fall to 30 lb. on reaching its engine. With engines placed underground it is customary to have longer lifts than with engines placed on the surface. This is easily understood; with an engine at the top and the pump at the bottom, the long connection and numerous joints are against excessively long lifts, whereas with engine and pump both below and close together we have only one long continuous column, namely, the water, to deal with, and it becomes practically a question of strengthening the parts. For surface engines 100 yards of a lift is usual, 150 yards is considered high, and 200 yards practically the limit. But with the former, 350 yards is not uncommon. Such very high lifts are more than questionable, the strain upon the engine and upon the lower pipes is nearly 500 pounds per square inch, and such excessive pressures are good neither for pipes, joints, nor pumps. The better plan is to have shorter lifts, and place a separate engine at the bottom of each lift. But in every case, whether with engines placed on the surface and with one or several lifts, or with engines placed underground, and in one, two, or more lifts, the pumping machinery should be equal to double the work it will be called upon to do.

Then, as regards the height of pump above the water, that is the vertical height of suction. Theoretically, reckoning an atmospheric pressure of about 15 pounds per square inch, water will rise to a perfect pump 34 ft. vertical; practically, it will not rise more than 27 ft., and if a pump is expected to work well the suction should never exceed 21 ft.

It is not often that all the water made in a mine will flow of itself to one point where the pump is fixed. Sometimes water is made at a lower point than the main pump, and if so must be dealt with by a small pump or pumps, or hauled out in tubs. At other times the water is made at a high enough point to fall to main pump by gravitation, but high ground intervenes, and a drain cannot be

cut with the same convenience in a mine as on the surface. Also, water may collect in both sump holes, and the pump only connects to one. In such circumstances that very useful appliance known as the siphon comes into operation. (See fig. 34.)

A siphon possesses no power, and can do no mechanical work—it cannot raise water from a lower level and permanently deposit it on a higher level. But it can take water from a higher level and place it on a lower level, and in doing so convey it over points higher than that from which it started. The siphon, theoretically, will, after the manner of the suction of a pump, cause water to rise over a point equal to an atmospheric column, namely, 34 ft., but, like a pump, it works not beyond in practice 27 ft., should never have to work higher than 21 ft., and the less the height the better it will work. A siphon will not work unless the delivery is below the feed and unless the pipes and joints are perfectly tight. If the line is not regular, as shown in fig. 35 or fig. 36, but irregular, as shown in fig. 37, air collects at the high places, and the siphon ceases work. The writer, some years ago, was consulted as to gas from a mine making its way into siphon pipes and stopping the action. If this was so, it was simply that the gas made its way in along with the water, and had the same injurious influence as ordinary air. It may be useful to a reader here and there just to explain briefly the action of the siphon, and how to construct it and work it.

The siphon is a bent tube open at both ends, and having one leg less in vertical height than the other—see fig. 38. If such a tube be filled with water and placed with the extremity of the shorter leg in a vessel also containing water, the water will flow out through the longer leg. If the vertical height from the surface of the water in the vessel to the top of the siphon be the same as the height of the other leg, no delivery will take place, because the pressure of the atmosphere will be acting on two identical columns, which will exactly balance each other, and there will be no tendency to motion in any one direction more than the other. But if, as shown in fig. 38, the delivery leg is longer than the vertical height from water level to highest point of siphon, equilibrium ceases. The

atmospheric pressure is the same on both sides, but one column is longer than the other, and the water flows down that, causing a vacuum. The pressure of the atmosphere acting on the surface of the water in the vessel forces the water up the shorter leg to fill up this empty space. Thus motion begins and continues.

In constructing siphons, the first consideration is that the pipes and joints should be such as to prevent inward leakage of air, otherwise the appliance is useless. Then it should be laid as regularly as possible, either horizontally or inclined, as already stated, because if irregular, as shown in an exaggerated form on fig. 37, air, which cannot be prevented entering along with the water, will lodge at the higher points, as shown shaded, and destroy the action. Of course such a defect might partially be remedied by inserting a vertical pipe at each of these points, but it is better not to need them. Provision will have to be made for charging a siphon at the commencement and occasionally when so much air has entered as to injure, if not stop, the work. To do this a tap is placed at the delivery end, to be opened and closed by hand, and a light clack placed in the pipe at the feed end. This clack will open and keep open when the siphon is at work, and close when the tap is shut at the other end, thus keeping the siphon charged. Such a clack is not needed at all in the actual working, indeed should be open the whole time, and if too heavy or carelessly made will do harm. The idea is to keep the appliance charged when working has ceased. A pipe is inserted at the highest point, or rises above the highest point of the siphon, for the double purpose of charging and allowing air to escape.

In addition to using the siphon between sump holes and in other parts of mines, the writer found it of good service on at least two special occasions. One was during a fire which had broken out underground in the neighbourhood of the furnace, and a stream of water was laid on from a reservoir on the surface. It was considered undesirable to cut through the reservoir bank, and the siphon enabled the water to be obtained from the reservoir over the bank. During this use of the siphon an interesting practical proof was obtained of the inertia of water bursting pipes. Almost every time the water was turned off suddenly one

or more pipes burst, owing to the sudden check upon the incompressible water. But when turned off gradually all went well. The other case was wanting to empty, or nearly so, a large and deep reservoir without cutting through the bank, the overflow being, of course, much too high. Again the siphon answered the purpose, and delivered the water into a drain passing through some low-lying land. A siphon has its maximum efficiency when the height the water has to rise is a minimum and the vertical fall not less than the atmospheric column—34 ft. In such a case the theoretic velocity would be obtained from the formula, velocity in feet per second squared = twice gravitation × height in feet, or = 64 × 34 = 2,176, square root of which would be about 46½ feet per second. This is the maximum velocity, and would be reduced by friction dependent on length and size of siphon. For other cases the effective height could never be more than 34 ft., minus the height the water had to rise, and this would still further be reduced by the extent that the length of the larger leg was less than 34 ft.

Siphon at Waterworks.—An important local authority in Lancashire, having jurisdiction over some 20,000 people, has adopted the siphon, not directly for colliery purposes, but indirectly, inasmuch as it is used to supply water to a colliery population.

Up in a somewhat hilly part of the district an abundant supply of what, with a little filtration, proves excellent water flows into a deep and extensive stone delf, now disused. Taking this as a natural reservoir, or at any rate ready made, the question was how to convey this water a distance of two miles into the town, there being plenty of fall. To lay pipes into the reservoir, as is usually the custom, would have occasioned, in consequence of the depth and hardness of the stone, great expense; and to have fixed pumping arrangements to raise the water from the reservoir would have occasioned much expense at first in providing an engine and the needful steam generative power, and would have entailed some continuous expense afterwards, which would not have been lessened by the fact that the site was high, far removed from railway conveniences and the approaches bad.

Under all these circumstances a siphon seemed just the thing for producing a maximum of effectiveness with a minimum of expense, and a siphon was accordingly placed. The short leg is vertical, and measures some 30 ft. The long leg forms an inclination of about half a mile long, with a vertical fall rather exceeding an atmospheric column, and discharges into a large filter bed. The pipes, being large, would, if working anything like continuously, empty the reservoir and disorganise the siphon. Accordingly, a valve is fixed at the lower end of the long leg, and either allows full discharge or no discharge, or regulates the delivery to anything that may be required. When the reservoir is what may be termed full, the water is within 12 ft. of the highest point of the siphon, and the work goes on well when the level of the water is anything between this and 21 ft. But when the vertical depth from the highest point of the siphon to the level of the water exceeds this 21 ft., the arrangement at once has a lessened efficiency. A pipe for the exit of air is fixed in accordance with the principles laid down in this article.

The writer has been much interested in this thoroughly useful application of a useful contrivance, because he was consulted on the subject when first proposed, and has had several opportunities of satisfying himself as to its efficiency during the few years it has been at work. All the pipes must, of course, be perfectly sound, and carefully and regularly laid, and the joints all made with great care. As a consequence, there has been, and will be, no trouble.

Such form our introductory remarks as to pumping arrangements, including, as was thought opportune, some particulars of that useful and close ally of the pump at collieries, namely, the siphon. The succeeding chapters will endeavour to deal with some early pumping machinery leading up to our own time.

CHAPTER VIII.

PUMPING ENGINES AND APPLIANCES.—HERO TO SAVERY.

The Early History of the Steam Engine—The Pneumatics of Hero—Mr. Bennett Woodcroft—Vice-Chancellor Greenwood—Knowledge of Expansion of Steam, the Slide Valve, the Clack, the Metallic Piston and Metallic Cylinder before the Christian Era—Fire Engines—The Ancient Theory of a Vacuum and that Water under the Action of Fire was transformed into Air—Porta—Branca—Solomon de Caux's Appliance for producing a Fountain by the direct force of Steam—The Marquis of Worcester; his *Century of Inventions* and his Water-commanding Engine—What Lord Worcester actually accomplished—Sir Samuel Moreland, Master of Mechanics to the King of England—Dr. Papin, his Boiler Safety Valve, and his Engine Piston—Captain Savery and the "Miners' Friend"—England's Need of Pumping Engines.

In presenting a rapid historical sketch of pumping engines and their appliances one is bound to give something of a sketch of the early history of the steam engine itself, because all the early engines, down to the times of Savery, Newcomen, and Watt, when applied to any practical use, were employed almost universally for pumping water. So far as can be gathered, Hero's æolipile was either merely a toy, or if any work was done with it there is no evidence that water was raised, and Branca, the Italian physician, applied his mechanism to the purposes of his profession, and pounded drugs with it, and De Garay, in Spain, used steam for giving motion to ships. Still, with very few exceptions, the early steam engine was a pumping engine, and such figures as may be presented illustrative of the article will show it applied in that way.

It is not possible to fix the exact period at which the power of steam was understood; there is great scarcity



FIG. 39.—PLAN OF BRONZE CLACK, IN USE TIME OF HERO, 200 B.C.



FIG. 40.—ELEVATION OF BRONZE CLACK, IN USE TIME OF HERO, 200 B.C.

[*To face page* 59.]

of authentic records of ancient times. This, perhaps, was attributable largely to the fact, not that the ancients appreciated engineering success less than we do, but they carried that appreciation to idolatry, and in the blindness of their superstitious worship treated those who possessed such knowledge as gods, and their real history has therefore been lost to us through the mists of antiquity. In a more recent period engineering knowledge fell into disrepute, being considered inferior to philosophy, and this condition of things existed till well on in the Middle Ages.

Perhaps the oldest written work on mechanism in which we have any reliable record of steam being used as a motive power, and of efficient mechanical arrangements generally, is contained in the Pneumatics of Hero, of Alexandria, an engineer who flourished 200 years B.C. This work has had many translations, but the most recent, and probably the best, is one undertaken by Mr. Bennett Woodcroft (who for many years did good public service in connection with patents), since deceased, who prepared all the necessary drawings, and who had the invaluable assistance of Principal Greenwood, of Owen's College, now the honoured and venerable vice-chancellor of our Lancashire University. This translation was published in 1851, and was dedicated to Prince Albert. It treats of the expansion of steam, and describes the slide valve, the spindle valve, and the common clack, and illustrates the application of a metallic piston to a metallic cylinder. It contains diagrams and descriptions of nearly one hundred inventions which would now be classified under the head of mechanical engineering, and all so clearly described as to leave no doubt of an advanced knowledge among the ancients of that class of mechanism of which the steam engine has been structurally compounded.

The first series of sketches describes the siphon, about which something was said in our last chapter. Figs. 39 and 40, taken from the Pneumatics of Hero, illustrate a bronze clack for a pump. The description given is peculiar, but very explicit, and is as follows:—Take two rectangular plates of bronze, of the thickness of a carpenter's rule and measuring about one finger's breadth on each side. When these have been accurately fitted to each other

polish their surfaces so that neither air nor water may pass between them. In the centre of one of them bore a circular hole about one-third of a finger's breadth in diameter. Then, applying one side of each, let the plates be attached by means of hinges so that the polished surfaces may come together. When the valve is to be used fasten the plate having no opening over the plate that has an opening, and any air or water forced through will be effectually confined. For by the pressure exerted the hinges move, and the plate without the opening opens readily to admit the air or water, which, when enclosed in the air-tight vessel, presses on the plate having no opening and closes the aperture through which the air was forced in.

Fig. 41, from the same work, is a fire engine of those early days, which would do creditable work with a fire brigade of these advanced times. The figure and description are again all that could be desired. The siphons (!) used in conflagrations are made as follows:—Take two vessels of bronze (the cylinders) having the inner surface bored on a lathe to fit a piston. Let the cylinders communicate with each other by means of a tube placed near the bottom, and the ends of this tube fitted with clacks adjoining the cylinders and opening outwards from the cylinders. In the bottoms of the cylinders pierce apertures covered with polished hemispherical cups, through which insert spindles soldered to, or in some way connected with, the bottoms of the cylinders, and provided with shoulders at the extremities that the cups may not be forced off the spindles. To the centres of the piston fasten vertical rods, and attach to the upper end of these rods the beam, working at its centre about a stationary pin, and having some play to work about the pins which form the attachment on the piston rods. A vertical tube communicates with the horizontal tube attached to both cylinders, and this vertical tube branches into arms, which are provided with small pipes, through which water can be forced up. Now, if the cylinders are plunged into a vessel containing water, and the beam be made to work at its extremities, the pistons, as they descend, will drive out the water through, first, the horizontal tube, up the vertical tube, and out at the nozzle, which can revolve.

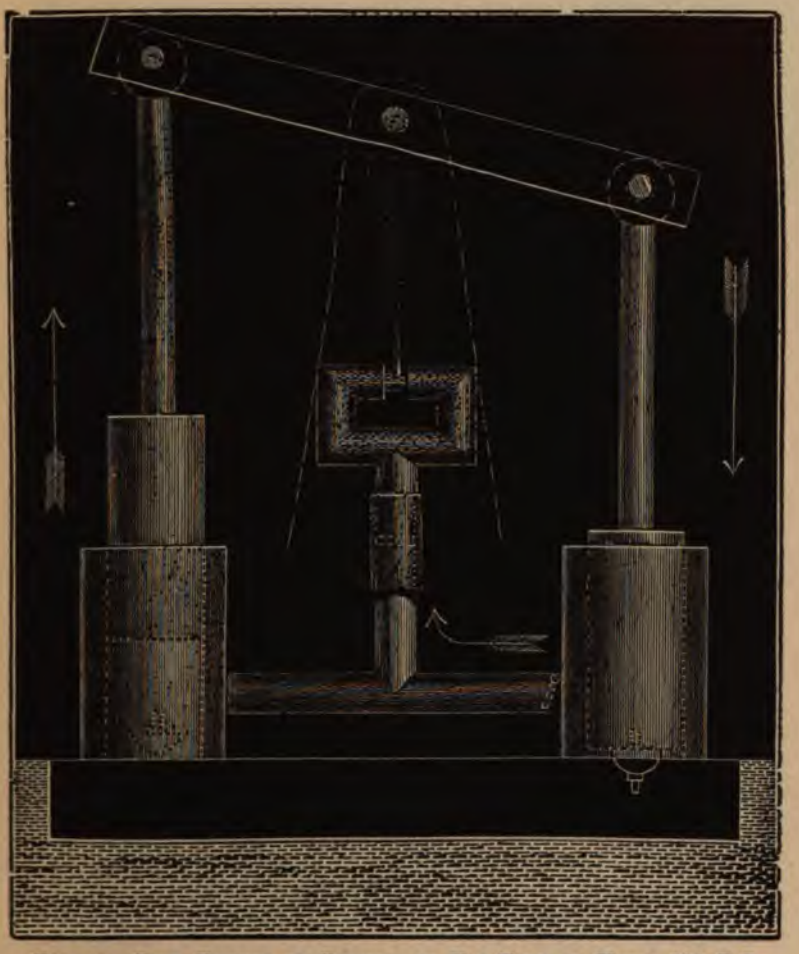


FIG. 41.—FIRE ENGINE OF BRONZE, IN USE TIME OF HERO, 200 B.C.

[*To face page* 60.]

For when a piston rises the hemispherical cup rises, and affords an opening through which water rushes into the cylinder, and the clack on the horizontal tube closes. When this piston descends the operation is reversed, the hemispherical cup closes, and the clack in horizontal tube opens, through which the water is forced and driven outwards and upwards. The action of the other piston is the same. The nozzle being made to revolve can direct the water in any angle of one plane and to enable the jet to play at any angle of any plane, the upright joint is made with a joint which enables the upper part of the tube to turn round. This arrangement, whereby the jet of water could be made to play in any direction, is very simple and exceedingly beautiful, and worthy the skilled mechanics even of the present age. Who, after reading descriptions and examining drawings such as these of the valve and the fire engine, can claim a monopoly in engineering knowledge for the times in which we live.

But the difficulty that occurs to the readers of Hero's Pneumatics is that, writing 200 years B.C., he says in his preface that he has "thought proper to arrange in order what had been handed down by former writers and add thereto his own discoveries," but the misfortune is he does not point out in any part of the book which inventions are his own and which belong to former writers. But when we speak of the ancients we do not refer to periods merely a generation or even a century or two previous. We go back through the ages and refer to something like a thousand or two of years. We can therefore be satisfied that certainly two thousand, and possibly four thousand years ago, steam engines had an existence, and appliances were in use for pumping water.

Hero's idea was that water, when consumed under the action of fire, was transformed into air, and in this respect his knowledge was perhaps not so advanced as our own; but he understood clearly enough that air was matter, and his ideas as to a vacuum, written at so remote a period, do him credit. Hero says, when they wish to fill with water the round medical glasses which have long necks they suck out air which is contained in them, and closing the orifice with the finger they insert them in the water, and on removing the fingers the water

is drawn up into the vacuous space, in contradiction to the usual law of liquids. If this distinguished writer lacked some knowledge of the action of the steam and the engine which we possess now he was clearly aware that the water in its changed condition, whether it was air, as he called it, or vapour, which we call steam, possessed its power by reason of the heat obtained from the fire. And it would be well if more of our students at the present day would realise more keenly and study more carefully the fact that the steam engine, however applied, whether to pumping or other work, is, if not a fire engine, purely a heat engine, and just as steam possesses work, or the power of doing mechanical work in proportion to the heat it contains, so will an engine do more or less work with a given quantity of steam in proportion as the heat is utilised between the entrance to and exit from the engine. We cannot find that steam-power was used in Hero's time for pumping, but the figs. 39, 40, and 41 show that pumping machinery of a good description existed, and was used in those early days.

A very long time indeed had to elapse before much progress was made. It is hard to believe that for so many hundreds of years nothing at all was done in introducing machines which should utilise steam-power; but the Romans, who were all-powerful for a long period, and who were brave enough in the field and eloquent enough in the senate, seemed to be occupied with fighting and speaking, and did nothing at all for the mechanical arts, and certainly nothing in connection with the steam engine. Then came the darkness of the Middle Ages, and it was not till the dawn of knowledge succeeded that darkness that the light reflected from the works of Hero rekindled the flame of mechanical invention. Italy, which was more in the vanguard of learning in those days than, unfortunately, she is now, first lighted the flame, and several translations and editions rapidly succeeded each other, forming the popular productions of the young art of printing. So eagerly were these works read that in one century alone—the sixteenth—nine editions were issued, and of the seeds of knowledge so widely sown some fell upon rich soil, and ultimately brought forth fruit with increase.



FIG. 42.—DE CAUS'S APPLIANCE FOR PRODUCING A FOUNTAIN BY THE DIRECT FORCE OF STEAM.

[To face page 62.]

Porta, writing in 1601, explained that the condensation of steam within a closed vessel may be made the means of producing a vacuum, and thereby cause water to ascend and fill the vessel. We make no mention here of attempts made with some degree of success in Spain in 1543 to propel vessels by power of steam, nor by an Italian physician, who, in 1629, used steam to communicate motion to mechanism, with which he pounded his drugs, because this article refers almost entirely to steam used for raising water.

In 1612 a Frenchman, by name Solomon de Caux, had settled in England, and was employed to design gardens, grottoes, fountains, &c., for the Prince of Wales. The spirit of invention aroused by the first translation of Hero's book had by no means been confined to Italy. It spread to many countries, amongst others England, and De Caux made some experiments to prove, which he did prove, that water could be raised by the power of steam. His apparatus, or, shall we call it pumping engine? is shown in fig. 42.

De Caux also wrote a book, giving the results of some of his experiments, in which he said that "the violence with which water is dissolved into air by means of fire is very great (the idea still held good through all these eighteen centuries that water, under the influence of heat, turned into air), and that a ball of copper containing water, if placed upon a fire, would surely burst." It had been proved in Hero's time that steam issuing from a boiler or goblet to which fire was applied would raise and support a light sphere. But this was mere child's play, and, like the æolipile, was only a toy. De Caux proved that fire acting upon water would heat that water, and so change the character of some that it would force the remainder up a pipe and throw it out at a higher level. Probably De Caux only intended this to act as a fountain, and only used it as such; but, whatever his intentions or applications were, he had arranged a contrivance, however rudely, which was capable of raising water, and that is what pumping engines do now.

After De Caux came that famous Englishman, the Marquis of Worcester, of whose pumping machine, to which he gave the high-sounding name of water-commanding



FIG. 45.—SUPPOSED WORCESTER'S PUMPING ENGINE.

[*To face page 64.*]

his contrivances, and those accounts were peculiar by their brevity, vagueness, and obscurity. Unfortunately, the vanity of the man was as great as the talent of the inventor. His famous book was entitled by himself "*A century of the names and scantlings of such inventions as at present I can call to mind having tried and perfected (my former notes being lost).*" The article referring to his great application of steam to pumping was as follows:—"I have invented an admirable and forcible way of drawing up water by fire—not by drawing or sucking it upwards, for that must be simply at such a distance, but this way hath no bounder if the vessel be strong enough. Having a way to make my vessels so that they are strengthened by the fire within them, and the one to fill after the other, I have seen the water run like a constant stream 40 ft. high. One vessel of water, rarefied by fire, driveth up 40 of cold water, and a man that tends this work hath but to turn one handle. One vessel of water being consumed, another begins to force and refill with cold water, and so successively, the fire being tended and constant, which the selfsame person may abundantly perform in the interim between the necessity of turning said cocks."

This description is tolerably clear upon several points. The height, 40 ft., would exert a pressure of nearly 18 lb. per square inch, so that a fairly good pressure of steam must have been generated, probably not less than 30 lb. As to vessels being made so that the pressure within strengthened them, no doubt many engineers of to-day would have been glad if more information on this point had been given. Pressure within modern boilers and cylinders certainly does not increase their strength. As he speaks of one vessel filling after the other, there must have been two, alternately discharging and filling. It is evident, too, that the force was not generated in the same vessels as the water to be forced up, and accordingly there must have been provided what might be termed two cylinders and a boiler. The principle of Worcester's engine might fairly be gathered from this description to be as shown in figs. 43 and 44, in which water falls to the vessels. But his admirers are not content with this, and would contend that his arrangement is really that shown in fig. 45, in which all that we have described is done, and,

in addition, a vacuum formed in cooling each vessel, and the water rises to a certain height. Worcester's own statement that his engine works not by drawing or sucking upwards would seem clearly and strongly to disprove this, especially as he stated elsewhere that using the pressure of the atmosphere was not a principle of his engine. The remark quoted above—that drawing or sucking was confined to such a distance—would seem to show that although he did not avail himself of atmospheric pressure, he understood its action, because the one clear principle of the pressure of the atmosphere is now, as then, that the column that can be raised under its influence is limited in height.

No useful purpose is ever served, nor is the reputation of a man ever maintained, by attempting to obtain for him credit for something which he never achieved. Such procedure throws doubts upon points previously considered beyond dispute. Lord Worcester was the greatest engineer of his day, and invented and worked, so far as can be gathered, the first real pumping engine—not an arrangement for merely spurting water into the air as a fountain, after the manner of De Caux, but a machine which could, and did raise continuously large quantities of water, as shown in figs. 43 and 44, by the action of steam generated in a separate boiler acting directly upon water in other vessels. His own statements go to show that he did nothing beyond this, and that although he believed his engine capable of forcing water to any height, the water thus lifted had in the first instance to fall to the water-commanding engine. To give Lord Worcester credit for less than he accomplished would be unfair, and to pay him compliments for something which he repudiates having accomplished, would be unjust to himself, and still more to the distinguished men who followed him. This much we can say, that this able and unfortunate nobleman did put into operation the first actual pumping engine, and that is credit enough for any one man. And, probably, but for the troublous times in which he lived, and his thoroughly consistent loyalty to his mistaken sovereign, a great deal more would have been accomplished, and clearer records and results left behind.

Sir Samuel Moreland.—After Worcester's death Sir Samuel Moreland, who styled himself under the practical and honourable distinction "Master of Mechanics to the King of England," endeavoured to obtain the patronage of the French Government towards a scheme for pumping water by the force of steam, but was unsuccessful in obtaining that patronage. No description of the apparatus or principle of its action is in existence, but Moreland made some experiments, the results of which have been preserved. Water being evaporated, he says, by the force of fire, its vapour occupies about 2,000 times a larger space than it did before, and can be made of great use to mankind, particularly for the raising of water according to the following particulars, which show the number of pounds weight which may be raised to the height of 6 in. 1,800 times a minute, in cylinders about half filled with water. [Here follow the particulars, which it is not necessary to give.] The remarkable fact, as showing that experiments really were made, and that with great accuracy, is that his estimate of the rate of expansion of water when converted into steam should very nearly coincide with the results which have been obtained by eminent engineers in modern times. To have arrived at such accurate results, with so little to guide him, speaks volumes for his perseverance and ability.

Few engineers have done more for engineering progress, and have done it more modestly, than the celebrated Dr. Papin, who introduced an appliance without which the steam engine, even for pumping, would have been extremely limited in its power. We have seen that the piston was actually in use in the fire engine in Hero's time, and probably long before; but Papin first proposed to act upon a piston with steam, and actually suggested the employment of steam for forming the vacuum under the piston, and also for raising that piston by its elasticity. In a paper describing his proposals, Dr. Papin shows that with a little water changed into steam by means of fire we can have an elastic power like air, but that it totally disappears when chilled and changes into water, by which means he perceived that he could contrive a machine in such a manner that with a small fire he would be able at a trifling expense to have a perfect

vacuum, which before he had endeavoured to obtain by gunpowder and had failed; and in another place he says that, by turning a small surface of water into vapour by fire, applied to the bottom of the cylinder that contains it, the vapour forces up the plug or piston in the cylinder to a considerable height, and which, as the vapour condenses, as the water cools when taken from the fire, descends again by the air pressure, and is applied to raise water out of the mine.

It would appear from all this that Dr. Papin not only actually introduced the piston for the steam to act upon, instead of, as in all previous arrangements, operating direct upon the water to be raised, but he understood quite clearly the principle of condensation forming a vacuum either to draw down the piston or draw up the water. In fact, he had in his mind and placed on paper the principle of the atmospheric engine, and, in addition, he invented and introduced the safety valve, which Savery adopted, and which we in our day would find it more than difficult to dispense with. Papin was more a philosopher than a practical engineer, and did more for others than for himself. His two chief inventions—the piston and the safety valve—are still, and will probably ever remain, vital elements in all pumping arrangements. His career was long, extending over almost the latter half of the seventeenth and a few years in the eighteenth century. But although a considerable notability both in England and abroad, his genius was somewhat erratic, and he could not confine his efforts at any one special work to obtain and sustain sufficiently decisive results. Other men, not more able, but with more perseverance, and of a more practical turn, reaped the harvest —Papin had sown the seed.

Savery.—About the end of the seventeenth century a really useful pumping engine was essential to the welfare of England. Mines then were not as mines now as regards depth and extent, but they were sufficiently extensive to play an important part in the nation's industries and deep enough to require some good appliances for keeping out the water. Many mines had to cease work, and others could not be started, for lack of pumping appliances, and it was at this time—illustrating again the

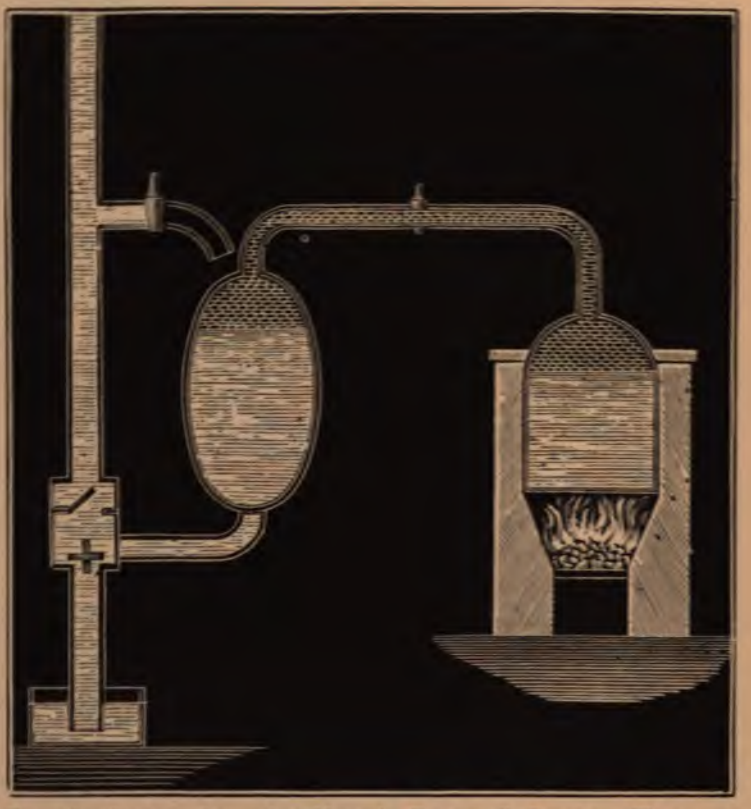


FIG. 46.—CAPTAIN SAVERY'S "MINER'S FRIEND;" DRAWING WATER UP TO IT AND THEN FORCING THE WATER ABOVE IT.

[*To face page 69.*]

adage that when the need arrives the man is ready—Captain Savery offered to mineowners and workers his "Miners' Friend." (See fig. 46.) There had been so many failures that people were grown hard of belief, and Savery had uphill work. Years after his engine had been invented and found practically efficient, very trifling progress had been made in extending its use, although mines were idle which it could have enabled to work, and men starving for whom it could have provided employment. At last the King had a model of the engine brought before him and experimented upon, and was so pleased with the success that he personally interested himself in the matter, and before royal influence difficulties vanished. Whatever doubt there was in Lord Worcester's case, there was none in Savery's. His engine comprised cylinder for the water and separate boilers for generating steam, and also for the first time the principle of condensation brought into use, and water not only forced up from the cylinders by pressure of steam, but drawn up to the same cylinders under the influence of vacuum produced by condensation. A point of interest in Savery's engine was, the clacks and cocks were all of brass, and the vessels made of the best hammered copper.

At this point the first portion of the historical matter connected with pumping arrangements ends. In the "Miners' Friend" of Savery an effective (as effectiveness went in those days) pumping engine, which would cause water to rise and afterwards force it to a moderate height had been provided, and by its means employment was increased, and the mineral wealth of the country developed. The engine was simple in construction, limited in the extent of its operations, and certainly not economical in working; but it was an improvement on all that had preceded it, and was a step nearer those more perfect arrangements gradually developed during the period of Newcomen and Watt, who were the first engineers to give us the pumping engines and the principles which still prevail to the present time. To this period we must devote the succeeding chapters, and so bring our historical matter to a close.

CHAPTER IX.

PUMPING ENGINES AND APPLIANCES.—SAVERY TO WATT.

The Correct Theory of the Vacuum—The Ancient Idea that Nature abhorred a Vacuum—Galileo—His Answer that Nature's Abhorrence of a Vacuum was Limited—The inoperative Pump in the Duke of Tuscany's Garden—Torricelli and his Researches and Experiments—Invention of the Barometer and Discovery of the real principle of Atmospheric Pressure—Savery's Engine—Newcomen's Improvements—Application of the Piston and the Beam and the Jet Condenser—Action of Newcomen's Engine and its Advance on all its Predecessors—Automatic Valve Gear—The Anecdote of the idle Lad—Working Results of Newcomen's Engine—Leupold—Blakey—Beighton—Smeaton.

We have seen that Captain Savery, in his "Miners' Friend," not only was able to raise water from his engine to a height dependent on the pressure of his steam, but he applied the new principle of atmospheric pressure to cause water to rise to the engine; and before going further it will perhaps be well to refer to the discovery of what enabled Savery to outstrip his predecessors and competitors, and enabled those who followed him to still further develope the usefulness of the pumping engine. We have already tried to show that pumps are no mere modern appliances, and that the action of the pump was in some form or other understood almost from the beginning of man's existence on the earth; but it was not until very recent times that it was understood that the atmosphere exerted a pressure upon everything with which it came in contact. Even now there are some amongst us who can hardly credit that the pressure on a man's body, for example, amounts to (roughly) 15 lb. for every square inch of surface. The idea prevailing amongst the ancients on the subject was a very simple one, namely, that "Nature abhorred a vacuum," and consequently, when

air was extracted, water rushed in to fill the void which was abhorrent to Nature, and hence a pump was enabled to work; and so things went on through the dark and middle ages, engineers and philosophers satisfying themselves and their followers with this view, until that remarkable century for engineering progress—the seventeenth.

These were the famous times of Galileo, and his afterwards equally famous pupil, Torricelli. There is no reason to doubt the accuracy of the story that, about 1640, some pumping appliances were being arranged in the garden of the Duke of Tuscany, and the arrangements were such that the water had to rise to the pump a greater height than 34 ft., and the water would not rise—why, no one could explain; Nature had always exerted its abhorrence to a vacuum previously—why not now? The difficulty was mentioned to Galileo, who, not long before, had suffered punishment for the great crime in those times of too much knowledge, and the philosopher cut the interview very short by remarking, with sarcastic truth, that probably Nature only abhorred a vacuum to the extent of 34 feet. And here the mystery would have remained—Galileo showing no inclination to remove the difficulty by discovering any solution—but his pupil Torricelli came to the rescue and gave the whole question careful consideration and thoughtful study—not extending over a few days, but during the remaining years of his great master's life, and perhaps more publicly and keenly after Galileo's death. The idea came to Torricelli that the "abhorrence of Nature to a vacuum" must be due to some discoverable cause, more especially as a limit to that abhorrence had been reached, and he thought the pressure of the air might have an influence arising from its own weight. If this were so, then the pressure which supported a column of water would support a column of something else—greater or less according as the substance supported was lighter or heavier than water. Torricelli made his famous experiments with mercury and found his idea correct. The column of mercury supported in a vacuum was exactly in inverse proportion to the weight of mercury and water. This was a remarkable discovery, but Torricelli wanted further proof of the accuracy of his views, and he thought

of the supporting a column of mercury or water in a vacuum is due to the weight of the atmosphere, then that would be less on a mountain, where the height of the atmospheric column was less, and greater in a valley, where the height of the atmosphere was greater. He made these experiments, and to his delight they proved the correctness of the ideas he held. The column of mercury supported in a vacuum was less on a mountain and greater in a valley, and Torricelli had solved the mystery—had shown the true nature of a vacuum—namely, the influence of atmospheric pressure, and had not only placed at the disposal of engineers a discovery which opened out wider fields of usefulness for pumping engines, but had provided in the barometer one of the most useful appliances in the world, enabling the varying atmospheric pressure to be measured with ease and regularity.

It might slightly add to the interest of this article to mention the efforts of others in the same direction of Torricelli's discoveries, and would certainly add to its length, but it would almost amount to needless repetition, and enough has been said to show how the nature of a vacuum and the principle of atmospheric pressure came to be understood, and it is not doing injustice to other eminent men to say that Torricelli, treading in his master's footsteps, proved himself, in this particular discovery, foremost of them all. Captain Savery availed himself of these discoveries and applied them in his "Miners' Friend." It may be suggested that, this being the case, all that was original in Savery's engine, the credit of it belonged to some one else. As a discovery unquestionably it did, but Savery applied it practically and proved its adaptability to useful work. There always have been, and always will be, theorists and philosophers who discover new ideas, and practical geniuses who put such ideas into practical form. One is necessary to the other; and in such discoveries and applications as this, there is abundant room for paying just tributes to them both.

Savery's pumping engine then, was one in which unquestionably the water was caused to rise to the vessel, and afterwards by steam forced up to another height.

The steam acted directly upon the water, and even in these modern days of pulsometers and injectors few people argue that direct contact of steam and water is an effective or economical method of pumping. The height to which the water could be forced was limited by the pressure of the steam, and this, owing to the weakness of the vessels, together with the loss by condensation, was very slight—20 lb. or 30 lb. would probably be considered a good pressure in the steam generator, and this would hardly allow a larger effective force than 15 lb., being about equal to an atmospheric column. The result would be that in a pit of any considerable depth, a "Miners' Friend" would have to be fixed each few yards. It was evident that although by means of this pumping engine good work was being done, the depth from which it could, with any pretensions to economy, raise water was not very great, and mines lying at any considerable depth below the surface, were beyond even this, the best pumping engine which had as yet been introduced.

Newcomen.—When any great idea is being developed and brought to practical perfection, the working of it out is left to no one man, but several—in most cases many—minds are busily engaged upon it, approaching the same issue in different ways, and arriving at perhaps nearly the same result in a different manner. Very many minds were engaged on the steam engine during the end of the seventeenth and the commencement of the eighteenth centuries, and all attempts tending to the introduction of a successful pumping appliance were followed with great interest. Newcomen was not trained, as we understand it now, to be an engineer—he scarcely could have been when there were as yet neither engines nor engineering—but he was a born genius with engineering inclinations, and he will ever be held in just and great esteem as the inventor of the really useful atmospheric pumping engine. In engineering, as applied to pumping, Newcomen was in advance of all the men of his time. We have seen that Papin and Moreland put their ideas on paper, and even made experiments, exceedingly interesting in themselves and productive of useful information; but they stopped at this, and neither of these eminent men constructed a useful machine. Newcomen, who was

nothing if not practical, saw clearly enough how Papin, Moreland and Savery could all be surpassed. He made the experiment of introducing steam under a piston moving in a cylinder, and formed a vacuum by condensing the steam by an affusion of cold water on the outside of the steam vessel, and the weight of the atmosphere pressed the piston to the bottom of the cylinder. This was the first form of the atmospheric engine, which with some excusable exaggeration was some half century ago pronounced the simplest and the most powerful machine that had ever been invented.

Unquestionably, Newcomen was on the correct track of improvement. The "Miners' Friend" only utilised atmospheric pressure to the extent of an atmospheric column, which in theory does not exceed some 34 ft., reckoning an atmospheric pressure of 15 lb. per square inch, and in practice does not much exceed 21 ft. But in Newcomen's arrangement, provided the piston were large enough, and the pumping gear strong enough, the atmospheric pressure could be made to act through an unlimited height.

Savery's engine acted by the steam which exerted the power being directly in contact with the water to be raised, and accordingly the power exertable was dependent on the steam pressure. Newcomen's appliance had no contact between the water to be lifted and the steam, and by merely increasing the size of the piston the power was unlimited. Savery was compelled to use dangerously high-pressure steam, and run the risk of accident from bursting the vessels. Newcomen had no danger, because he had no pressure, the force of steam within the boiler not being greater than the pressure of the atmosphere without.

Like most men who ultimately accomplish great work, his early career was beset with difficulties, and one serious obstacle was that as the method of procuring a vacuum by the condensation of steam was employed by Savery, and secured to him by patent, he had to enter into an arrangement with Savery, and they worked together for several years. This was somewhat unfortunate for Newcomen, because his engine was entirely different from Savery's, and he really owed nothing to him. Indeed, some early writers urge that so far from Newcomen's



atmospheric engine being merely an improvement on Savery's, Newcomen was as early in his invention as Savery, only the latter being nearer the court, had obtained his patent before the other knew it; and on this account Newcomen had to make a virtue of necessity, and take Savery into partnership.

Fig. 47 shows Newcomen's earliest atmospheric pumping engine, which, described generally, consisted of a beam, with a piston at one end working in a cylinder open at the top, and connected with the boiler at the bottom. At the other end of the beam were the pump rods for raising the water. The rods being heavier than the piston, their descent drew up the piston, the communication between the cylinder and boiler being open during the operation, thus allowing the cylinder to fill with steam. When this upward stroke of the piston and downward stroke of the pump was completed, the communication between the cylinder and the boiler was closed, and cold water applied to the outside of the cylinder, condensing the steam, and thus forming a vacuum. This vacuum below the piston enabled the atmospheric pressure above to act with full force, and the piston, under its influence, was forced down, and the pump lifted the water up. Provision was made for the water, the result of condensing the steam, to pass away, and the action commenced again. Fig. 47 shows the Newcomen engine of the early type with water for condensation applied on the outside of the cylinder. The balance weight is on the pump rods, and the piston has just reached the top of the cylinder.

The further improvements which Newcomen introduced into his engine comprised, as shown in fig. 48, the injection of the water for condensation into the cylinder, thus effecting quicker condensation and better vacuum, also self-acting mechanism for the opening and closing of the valves. A sort of fable is given in most books that this arrangement was the accidental discovery of an idle lad, who had to mind this engine and work these valves, and who, in his excessive love of play, made a contrivance whereby these valves and cocks opened and closed themselves, and made the engine self-acting. A very pretty story, and no doubt some useful discoveries have been made in a strange fashion, but it is hardly likely that

Newcomen would place one of his engines in charge of an idle lad; and indeed the story is not true. In a letter addressed to the writer several years ago, Mr. Bennett Woodcroft said that in some researches he had made he had found such mechanism attached to very early engines of Newcomen's, and had satisfied himself that Newcomen himself made his engine self-acting. Fig. 48 shows the engine as improved and arranged for internal injection of the water for condensation. In Newcomen's early engines the cylinders were of brass, the piston also being a circular brass disc, on the upper side of which a leather flap was secured, kept soft and air-tight by means of a stratum of water, a few inches in depth, constantly lying upon it. The boilers, as in Savery's arrangement, were of copper. In the latter engines the use of water inside the cylinder necessitated the drawing off of the condensing water as well as the water resulting from the condensation of the steam. This was effected by the application of a pipe called the eduction pipe, which issued from the bottom of the cylinder and was carried down a few feet. Also the water which entered the cylinder carried with it a certain quantity of air, which, if allowed to remain, would destroy the vacuum; and to prevent the accumulation of this air, a snifting valve was provided, which, opening upwards, and sitting in a little cup of water, allowed air to be blown out of the cylinder without allowing air to enter. The advance in pumping efficiency which Newcomen at once enabled to be made will be seen from the fact that one of his early engines fixed at Dudley raised water from a depth of 50 yards—which, under Savery's direct-action arrangement would have required nearly 100 lb. pressure of steam, whereas Newcomen only used that of the atmosphere. It grew rapidly in favour, and mineowners, who had never cherished any fondness for or confidence in the "Miners' Friend"—limited in its power and dangerous in its use—recognised in Newcomen's appliance a pumping engine of almost unbounded power and quite safe in operation, and before many years they were in use all over England for draining mines. Fig. 48 shows the later engines of Newcomen, in which the water for condensation is applied by injection into the cylinder. The snifting valve is shown for reliev-

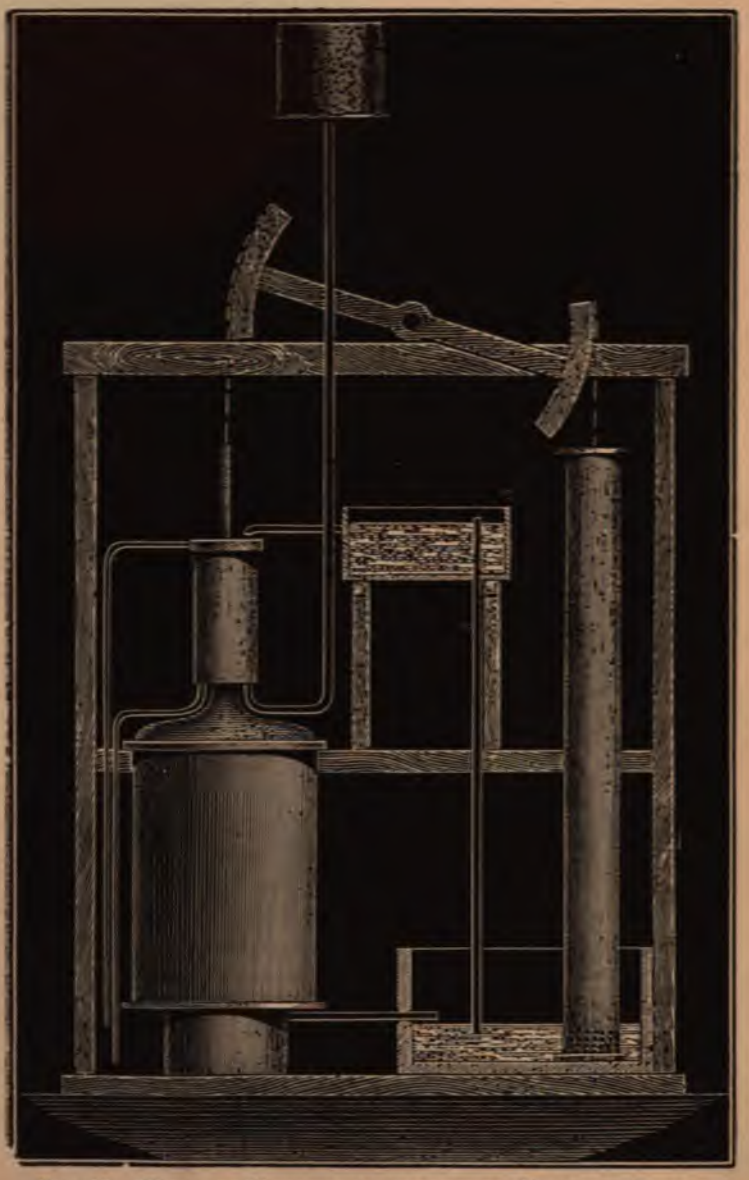


FIG. 49.—MODEL OF NEWCOMEN'S ATMOSPHERIC PUMPING ENGINE IN GLASGOW UNIVERSITY.

[*To face page* 77.]

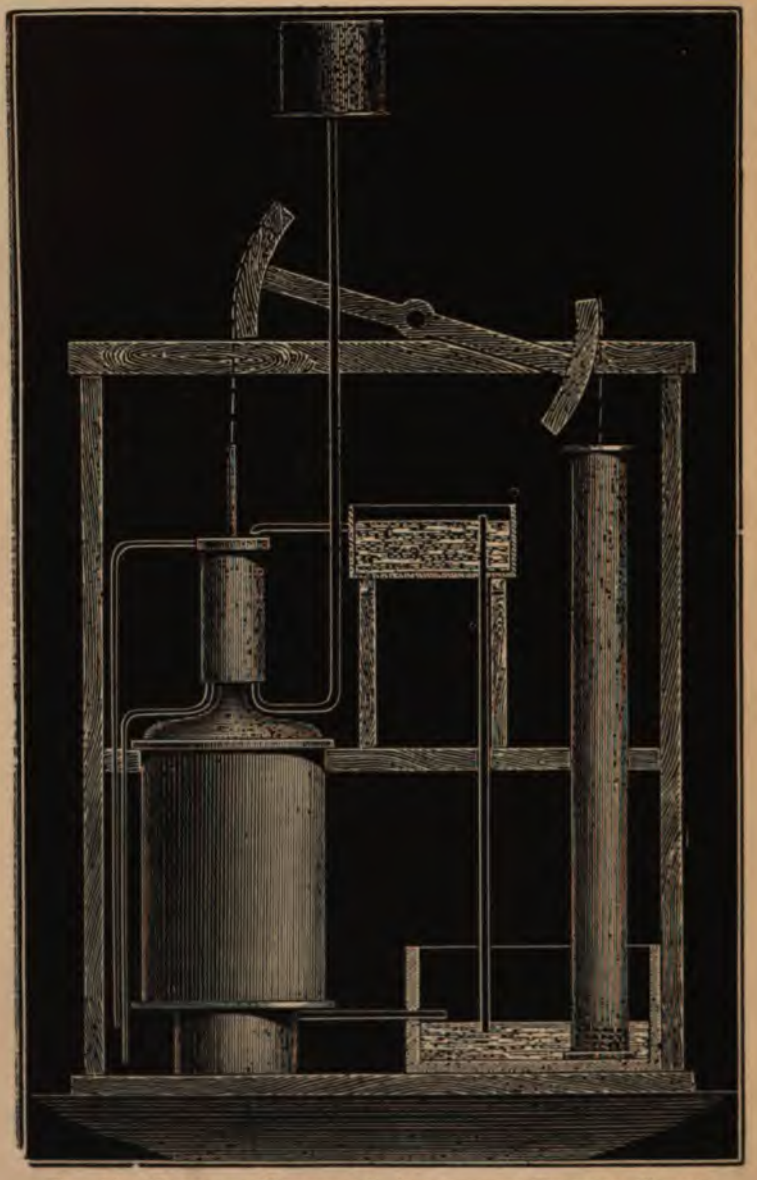


FIG. 49.—MODEL OF NEWCOMEN'S ATMOSPHERIC PUMPING ENGINE IN GLASGOW UNIVERSITY.

[*To face page* 77.]

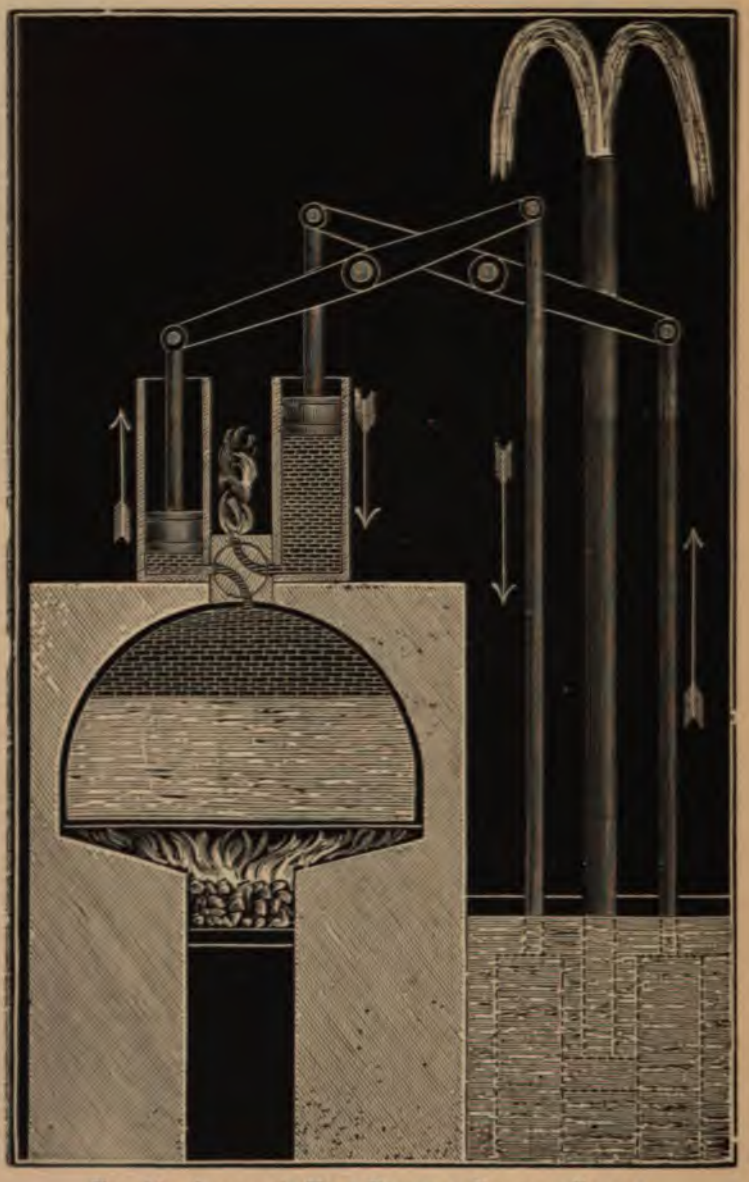


FIG. 50.—LEUPOLD'S HIGH PRESSURE PUMPING ENGINE.

[*To face page 77.*]

ing the cylinder of air. The upstroke of the piston has been completed and the injection turned on ready to commence the down-stroke of the piston.

Our sketches of Newcomen's engine will be made more complete by fig. 49, which represents the model belonging to the University of Glasgow, and which afterwards, in the hands of Watt, led up to so many remarkable discoveries. The boiler was about 9 in. diameter, the cylinder was of brass, 2 in. diameter, and the stroke 6 in. It was an exact copy of a real engine.

Leupold.—The pumping engines with which this article deals owed their power to the pressure of the atmosphere, made effective by producing a vacuum by condensation, but the old principle—namely, that of doing the work by the expansive power of steam—was not lost sight of, and to Leupold the eighteenth century was indebted for a high pressure engine with considerable effectiveness and designed with much ingenuity. (See fig. 50.) The cylinders—for there were two—were open to the atmosphere at the top, and the steam acted only under the piston. The boiler was placed under the cylinders, as was the practice then. The pistons were attached to beams, which, at their other ends, worked the pumps. About the most ingenious part of the appliance was the arrangement for enabling one communication not only to serve for admission to both cylinders, but also to allow exit, and was known then as now as the "four-way cock." After the steam had performed its work of raising the pistons, it was allowed to escape into the atmosphere. The author, if not exactly the inventor of this pumping appliance, with a modesty unusual amongst the early engineers, claimed little or no credit for himself. He ascribed the whole merit to Dr. Papin, to whom he said he was indebted for the idea of employing the elastic force of steam to raise water, and also because the "four-way cock" was copied from Papin's engine. At first this arrangement had to be so constructed that the weight of the piston end of the beam was sufficiently greater than the pump end to make of itself the descending stroke, and this, of course, would either make the engine very limited in its action, or the piston and rod had to be very heavy. This, however, was remedied afterwards by so connecting the two beams that

the ascent of the one compelled the descent of the other. Leupold's was a very successful effort to produce a high pressure pumping engine without condensation, and was exceedingly simple, and constructed quite on correct principles, but did not command much attention, because it was overshadowed by the atmospheric engine; and so much did the latter arrangement increase and continue in public esteem, that it was very many years before high pressure appliances could even have fair play. But Leupold deserves recognition in all articles of this kind, for his unquestionable ability and thorough knowledge of the subject, and for his great modesty, the excess of which probably lessened his chances of success. Fig. 50 shows the Leupold engine just changing the stroke, one piston being up and the other piston down, the flow of water, of course, being continuous.

Blakey.—After Leupold's efforts there was a tendency to fall back upon the idea of Savery, namely, to have no piston, and still avoid the defect arising from direct contact of steam and water, and this was done by interposing a quantity of oil between them, which from its less specific gravity floated on the surface of the water, and operated as a non-conducting piston. Fig. 51 shows Blakey's engine and boiler. There were two receivers, one placed over the other. The appliance was not a practical success, and an accident in connection with one of the engines in Cornwall, one of the vessels bursting, although the pressure was lower than that at which it was intended to work, destroyed all chances of success. A notable feature of the arrangement is the boiler, specially adapted for rapid generation of high pressure steam, and of a character likely to be strong. This boiler seems to foreshadow the small tube boilers, of which so many are in use in our own time. Blakey made his pumping engine so far complete that a series of levers effected automatically the opening and closing of the cocks.

Beighton.—It was not to be expected that engineers would rest content with even the wonderful improvements of Newcomen; many endeavours were made to effect still further improvements, and few were more successful than Henry Beighton, a skilful engineer, hailing from the County of Warwick. Amongst other improvements

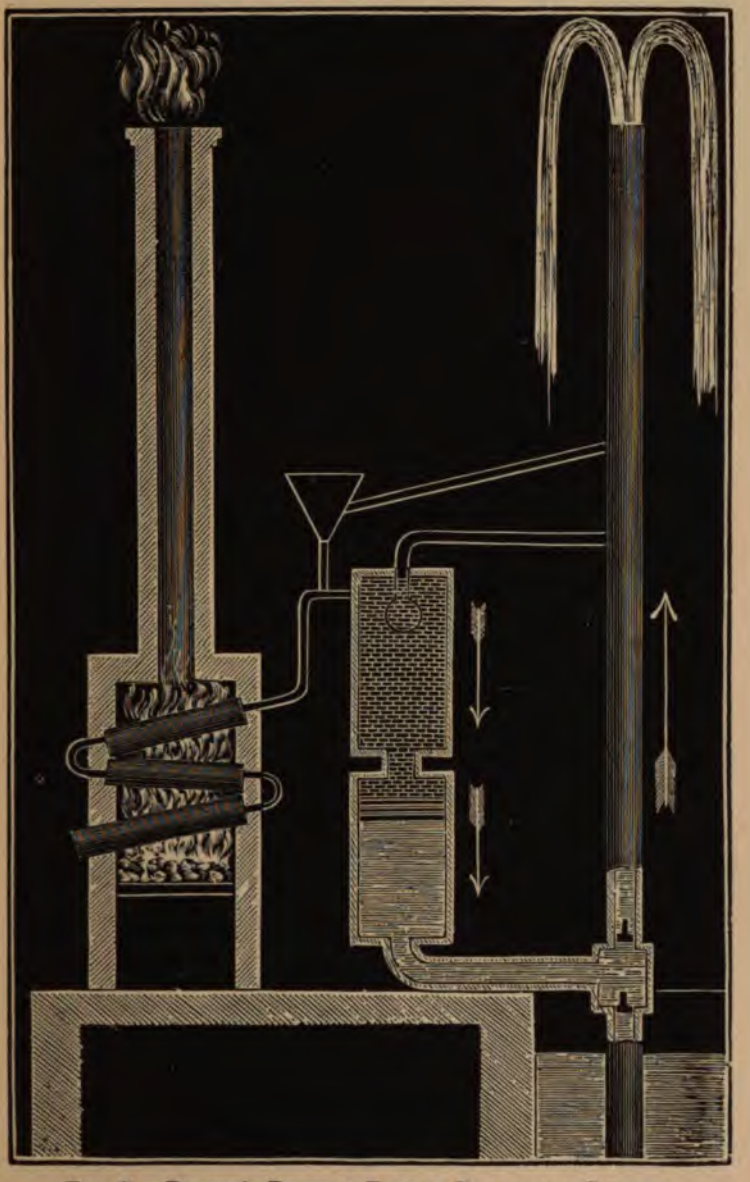


FIG. 51.—BLAKEY'S PUMPING ENGINE, BOILER AND CHIMNEY.

[*To face page* 78.]

Beighton introduced the steel-yard safety valve, which although certainly not in these days the most perfect of safety valves by any means, was a wonderful advance on any safety valve preceding it, and probably no appliance in engineering has been much more popular or more generally used. He also applied himself with great success to the simplification and improvement of the mechanism for opening and closing the valves, and introduced the handgear, a contrivance which, with some slight modification, is employed in many modern engines. Besides this, Beighton gave a better arrangement and form to the parts already in use, and paid more attention to the proportion of the parts among themselves, and to the work which they had to perform, besides introducing greater neatness and accuracy of workmanship into his engine than had previously been attempted. Fig. 51 shows the Blakey engine, and the steam is acting upon the film of oil which separates the water from the steam, and the water is being forced up. In all the foregoing sketches only enough is shown to explain the principle of the contrivances without introducing valves and gearing to complicate the figures.

Smeaton.—In all Newcomen's atmospheric engines, the steam cylinder stood upon or over the boiler. It was very difficult, almost approaching impossible, to keep the boiler and cylinder so firm in their position as was necessary to preserve the accuracy of their movement, and the least want of precision in the opening and shutting the injection and steam valves, was attended with disastrous effects. Engines, however well made, were subject to jolting and shaking at the moment when the beam had its motion reversed, which loosened the boiler from its brickwork in a few days. Smeaton, amongst other improvements, endeavoured to secure stability by bolting the cylinder to strong timber beams resting upon massive walls, totally unconnected with the boiler, and even then during the upward motion of the piston the boiler and cylinder were lifted, and depressed to an equal extent in the downward movement. To obviate these disadvantages the parts were sometimes arranged differently, the cylinder was sometimes placed beside the boiler, and it was fastened to a solid mass of wood or stone, quite distinct

from the boiler, and this was found a decided improvement. Not much had been done since Beighton's time which had any great effect in diminishing the enormous waste of fuel which took place in even the best engines of that time. Newcomen had done much in this direction. His first engines reduced the previously enormous consumption to about 32 lb. of coal per horse-power per hour, and his later engines did the same work with less than 30 lb. Smeaton tried to do something by conducting the flame through a great length of circuitous channel before it entered the chimney, with the hope of arresting a greater proportion of the heat by detaining the heated gases a longer time under the boiler. But the draught was so weakened that more was lost through imperfect combustion from this cause than was gained by the larger retention of the heated gases. Smeaton, however, did very excellent service to the cause of engineering by obtaining correct results of all the engines at work, erecting many engines himself, and noting their results, and making numerous experiments, thus enabling him to lay down the best proportions on which these engines should be constructed, and, indeed, enabling the mine-owners to get as much water as possible pumped with the least expense that Newcomen's atmospheric engine was capable of. But neither Beighton nor Smeaton, able as they were, and although their improvements were valuable and considerable, nor any of the other engineers of that time, altered or affected the principles of the atmospheric engine introduced by Newcomen. It was left for James Watt to crown the edifice, and any series of articles on pumping engines and appliances must devote some little space to his enormous achievements. We propose, therefore to conclude our historical remarks by touching upon what this, the greatest engineer of his own or of any time, did for pumping appliances.

CHAPTER X.

PUMPING ENGINES AND APPLIANCES.—JAMES WATT.

Watt and Stephenson—The Stationary Engine a greater Invention than the Locomotive—Watt did invent the Stationary Engine in all its essential Principles—Stephenson did not invent the Locomotive nor any of its essential Principles—Defects of Newcomen's Pumping Engine—Limited in Power, and extravagant in Working—Watt's brilliant series of Inventions—The Separate Condenser—The Cylinder Cover and Gland and Stuffing Box—Steam Expansive and Double-acting Engines—Parallel Motion—Crank and Connecting Rod—Sun-and-Planet Wheels—The Governor and Throttle-valve—The Steam Jacket—The Indicator—The Dead Plate—The Counter—The Pressure Gauge—Consumption of Coal per Horse-power with Newcomen and with Watt—Investigations as to Latent and Sensible Heat of Steam—Improvements in Pistons—Pride in his Parallel Motion—Single-acting and Double-acting Engines—The Steam Jacket and Advantages claimed for it—How Steam may be used in the Cylinder—Non-condensing and Non-expansive—Condensing and Non-expansive—Non-condensing and Expansive—Condensing and Expansive—The Advantages of Condensing and Expansive Engines.

Writers at various times have endeavoured to place Watt and Stephenson side by side as eminent inventing engineers, the one the father of the stationary steam engine, and the other the originator of the locomotive. Even if this were so, Watt would stand pre-eminently ahead, because the making a practically perfect machine of the stationary engine was far away a more important result than making a really useful machine of the locomotive. The locomotive engine is a steam engine which moves itself as well as the work upon which its power is exerted, and once having perfected a machine which, stationary itself, should utilise the power of steam for

effecting movements of all kinds, it could only be a question of a comparatively short time the adapting of steam to work a machine which itself should move.

But even if the locomotive could claim equal importance as an invention, which it cannot, Stephenson not only was not the inventor of the locomotive, because there are some existing yet, notably one by Cugnot, in Paris, which worked before the great Stephenson was born; but few great principles of the locomotive owe their invention to him. The tubular boiler, the horizontal cylinder, the smooth wheel upon a smooth rail, the steam blast, the two cranks working at right angles, were all introduced as separate contrivances by separate people at different times. And to George Stephenson belonged the credit of being able to combine all the really good points of previous attempts, and by uniting them together to make a useful and successful machine. This alone would have been a great work for even a great man, but Stephenson is justly renowned all the world over, not so much for any inventions in the locomotive engine, but for founding a railway system, without which the locomotive would have been of very little practical good, and with which it has done wonders for mankind.

But James Watt, to all intents and purposes, invented in all its leading principles the steam engine as we have it now. No contrivance in the world's history has done so much for the human race as the steam engine. It has developed beyond all possible expectation old industries, opened out in all parts of the world new industries, increased our wages, cheapened our food, multiplied our comforts, brought the nations into close contact with each other, and, indeed, the best idea we can have as to the immense influence for good which it has had is to imagine what the world would be if all the steam engines were removed. When Watt took the good work in hand what was known in connection with the power of steam was, that acting upon a piston working in a cylinder it could be made the means of raising water out of mines from moderate depths; and the principle of atmospheric pressure and condensation forming a vacuum was understood. It was known that the atmosphere by its weight exerted a pressure of about 15 lb. per square inch, and

that filling the space under a piston with steam, and then condensing the steam by water, which would occupy when condensed a space of only about 1-2,000th part of its bulk of steam, thus forming under the piston an almost perfect vacuum, enabled the power or pressure of the atmosphere to be utilised above. This amount of knowledge enabled a machine to be constructed which could be used only for pumping water, and this only from moderate depths, and at a very great cost of coal per horse-power per hour, and any one engine could only effect a comparatively small amount of work. Watt started on his career, and devoted half a century to the perfection of this useful servant of the human race, and the efforts extending throughout a somewhat prolonged life resulted in the most brilliant series of inventions that the world has ever witnessed. He gave us the separate condenser, the cylinder cover and gland and stuffing box, the action of steam on both sides of the piston, the use of steam expansively, the parallel motion, the crank and connecting rod, the sun-and-planet arrangement of wheels, the governor and throttle-valve, the steam jacket, the indicator, the pressure-gauge and the dead plate in steam boilers. By means of these inventions the steam engine developed from being a costly machine doing a small amount of work of one kind only—namely, raising water—to become applicable to all manner of work, to any extent and at small cost. Newcomen's engine consumed something like 30 lb. of coal per horse-power per hour. Smeaton effected great improvements, and in even his early engines on Newcomen's principle managed with less than this, and in his later engines reduced the quantity to about 20 lb. It is given, on tolerably reliable authority, that Watt's pumping engines in their crudest form only reached 10 lb. of coal per horse-power per hour, and that in his own time his own improvements resulted in the work being accomplished with 3 lb. And no greater compliment can be paid him than the fact that so complete was his series of inventions that the engine to-day in all its leading principles is the same engine that Watt left us. And so efficient was his pumping engine that the average of the best modern engines will consume more coal per horse-power per hour than Watt's later engines did. There was some inclination

at one time to occupy his time with other matters, such as the locomotive, but it was well for his reputation and the world's good that Watt not only devoted himself during his long career to his one great and comprehensive work, the stationary steam engine, but so far as his influence went he kept his brilliant pupils Murdock and the rest from launching out into other things. Murdock's great genius could not altogether be confined to the working out of his great master's masterpiece, and he did, not altogether to Watt's satisfaction, devote his thought and energy to such works as the locomotive and illumination by gas. Watt evidently felt that the completion of this one work required and would justify the efforts of himself and all those who were associated with him, and he was right.

It is not intended in this chapter to deal with all Watt's inventions. One—that of the indicator—has been referred to at some length under the heading "Mechanical Ventilation," in Volume I.; and others, such as the governor and the sun-and-planet arrangement, and crank and connecting rod have no special connection with his pumping engine. There are others, however, which cannot fairly be omitted, such as double-action and expansive action of steam, the separate condenser, the cylinder cover and gland and stuffing box, the steam jacket, and parallel motion.

We have already seen and tried to show what had been accomplished by Newcomen; he had applied a piston in a cylinder open to the atmosphere at the top, and having a means of communication with the boiler below. The steam did no work by its expansive power, but by filling the space below the piston with steam and then applying water, condensation resulted, a vacuum was formed, and the pressure of the atmosphere operated effectively upon the upper side of the piston. Newcomen's was an atmospheric engine, not a steam engine, properly speaking. The condensation and vacuum were effected first by water being applied outside the cylinder, and latterly by injection of water into the cylinder. Watt, whose attention was first directed to the steam engine, not as an engineer, but merely as a mechanician, to examine and make needful repairs to the model of Newcomen's engine in Glasgow University, soon discovered that there

was something wrong, and he at once left the workshop of mere mechanical construction, and entered upon the unexplored regions of engineering research. He made experiments with the model, and was surprised that, although the boiler was large in proportion to the size of the cylinder, not nearly enough steam could be generated to keep the engine working. He constructed a boiler which showed how much water was converted into steam, and consequently how much steam was consumed at each stroke of the engine, and found that the quantity of steam used each stroke was several times more than the capacity of the cylinder. This proved conclusively enough that a very large proportion of the steam was lost by condensation against the cold metal of the cylinder. Note was also taken of the large amount of heat imparted to the injection water by a small quantity of water in the form of steam, and experiments proved that water in the form of steam could heat about six times its own weight of cold water to 212 degs. Fahr. These discoveries, made known to one of Watt's most eminent contemporaries, Dr. Black, were the direct cause of a clear exposition of the then not understood latent heat. Experiments also showed that the temperature at which water boiled increased and decreased as the pressure increased and decreased; and that in vacuum water would boil even below 100 degs. Fahr., so that to obtain even an approach to a perfect vacuum no temperature higher than 100 degs. would be at all effective. Thus Watt was gradually constructing in his own mind, from study and experiments, the principles of his engine, and the conclusion at which he arrived, at a comparatively early period of his considerations, was as follows :—To make a perfect steam engine it was necessary that the cylinder should always be as hot as the steam which entered it, and that the steam must be cooled down to 100 degs. Fahr. to obtain an effective vacuum. This was the problem to be solved, and the solution under Watt's indefatigable genius was found in the separate condenser. The idea on which this separate condenser was designed and constructed was, that if a communication were opened between a cylinder containing steam and another vessel, which was exhausted of air and other fluids, the steam as an elastic fluid would immediately

rush into the empty vessel, and continue to do so until it had established an equilibrium, and if that vessel were kept very cool by an injection or otherwise, more steam would continue to enter until the whole was condensed. To put these ideas into practice, Watt combined the separate condenser and the closed cylinder. This application of the cylinder cover was in itself an important advance, and changed the character of the engine from being a contrivance whose power was limited to utilising the pressure of the atmosphere, and made it a real steam engine, the power of which would be limited only by such limit as might be found in the elastic power of steam. It seems quite natural now that Watt should decide to have a closed cylinder, and effect the condensation of the steam in a separate vessel, so as to be able to keep this vessel as cold as possible, and on the other hand keep his steam cylinder as warm as required, to have no cooling influence upon the steam.

All very successful practical inventions apply some principle so simple in itself, and so clearly right, that the wonder is the discovery was so long postponed. Watt constructed his simple condenser and his closed cylinder, and his ideas proved to be quite correct. It was about this time that he made the experiments which proved that a cubic inch of water was converted into one cubic foot of water at atmospheric pressure, and also made researches into the question of latent heat. It was very well known that taking water in its three conditions of solid, liquid, and gaseous, when heat was applied to the substance in either the solid or liquid state the temperature increased up to a certain point.

Ice below 32 degs. F. would, by the application of heat, gradually and regularly increase in temperature until the melting point was reached, namely, 32 degs., at which point, however much heat was applied, there would be no increase of temperature till all the ice had become water. Then the temperature would again go on gradually and regularly increasing until the boiling point was reached, namely, 212 degs. F., and at this point the temperature could not be raised until all the liquid had become gas—that is all the water had become steam, after which the temperature would go on increasing again. This heat,

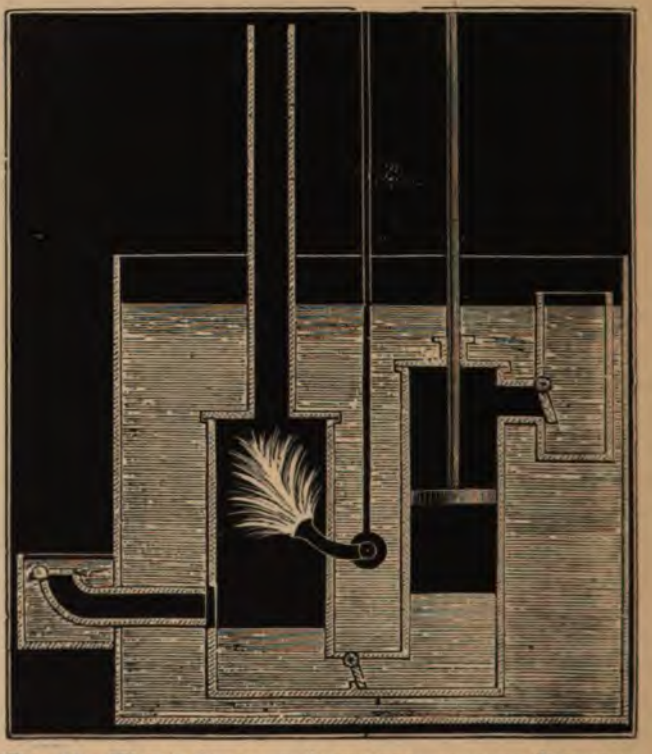


FIG. 52.—WATT'S SEPARATE CONDENSER, SHOWING INJECTION AIR PUMP, FOOT VALVE, DELIVERY VALVE, HOT WELL, SNIFTING VALVE AND CISTERN.

[*To face page* 87.]

which disappeared in changing the character of the substance was termed latent heat, and Watt proved by experiment that the latent heat of steam was between 960 and 1,000 degs. And he arrived at the important conclusion that the sum of the latent and sensible heat at different temperatures is a constant quantity, the latent heat increasing as the sensible heat diminishes, or, in other words, that a given weight of water in the state of steam contains the same quantity of heat whatever may be the bulk or density of the steam. These researches of Watt were of great service in increasing the knowledge of steam and in pointing out to him the direction in which improvements should be made; although, as a matter of fact, his conclusion that the total heat of steam was the same at all temperatures has since been found incorrect. The actual difference in the total heat of steam at different pressures and temperatures is about as follows:—At atmospheric pressure the sensible heat or the temperature is 212, and the latent heat 966, giving a total of 1,178. At 100 lb. absolute we have temperature 327, and latent heat 883, making a total of 1,210. At 200 lbs. absolute it becomes temperature 381, and latent heat 844, showing a total of 1,225, and at 300 lb. absolute the temperature is 417, and the latent heat 818, being a total of 1,235. So that Watt was not a great way wrong, even compared with the results from most elaborate researches a century later. Between atmospheric pressure and 300 lb., the temperature advances 205, the latent heat diminishes 148, and the increased total heat only amounts to 47, being about 4 per cent. So far from these figures proving inaccuracy, they go to show the wonderful care that Watt must have exercised in his experiments, and consequently the truthful results he obtained. The separate condenser (see fig. 52) was arranged to have an internal injection of cold water, and some means were required to free the condenser of this water and the products of condensation, which he thought of effecting by turning a pipe down a sufficient depth to overcome atmospheric influence. But it was found that air made its way into the condenser, and the non-removal of this would at once lessen and ultimately destroy the vacuum. An air-pump was introduced, which, without throwing much work upon the

engine, cleared the condenser of air and water, and thus enabled the maintenance of a good vacuum. Closing the cylinders at both ends necessitated a means whereby the piston rod could pass freely in and out and still prevent leakage of air in or steam out. The cover and gland and stuffing box were introduced, and have proved their efficiency and popularity by constant use to this day. Also something had to be done as regards making the piston tight. Newcomen's pistons were kept tight by water lying on the upper side, and being an atmospheric engine with no steam above the piston, this answered well enough, because, if water leaked through it only helped the vacuum below. This arrangement would not answer for Watt, with steam on both sides of the piston, and he tried piston rings of cloth and afterwards pasteboard. He also tried mercury, but "it found its way into the cylinder and played the devil with the solder." Ultimately, the metal ring fitting in a metal piston was reached. And as a further protection to the cooling influence of the atmosphere upon the cylinder a double cylinder was constructed with a space between, and into this space steam was admitted, which kept the inner or working cylinder warm and enabled the steam to have a truer action of the steam upon the piston. The fitting to the piston a rigid rod which was compelled to work in a straight line by passing through the cover necessitated the arrangement for connecting a straight-line motion of the rod to a circular movement of the beam, and hence came the simple and beautiful contrivance known as the parallel motion.

As compared with inventors who preceded him, Watt was not a vain man, although certainly much engineering learning might have made him mad; he was never tired of speaking of his parallel motion, and said, though not overanxious after fame, he was prouder of this than of any other mechanical invention he ever made. In speaking of it, he said he had started a new hare. He had got a glimpse of a method of causing a piston rod to move up and down perpendicularly, by only fixing it to a piece of iron upon the beam without chains or perpendicular guides or untoward frictions, arch heads, or other pieces of clumsiness. The invention was made in the latter end



of 1773, and a year later he wrote that the new central perpendicular motion answered beyond expectation, and did not make the shadow of a noise. The idea originated as follows:—On finding double chains or racks and sectors very inconvenient for communicating the motion of the piston rod to the angular motion of the working beam, he set to work to try if he could not contrive some means of performing the same from motions turning upon centres. After some time it occurred to him that two equal radii revolving on two centres, and connected together by a rod, in moving through arcs of certain lengths, the variations from the straight line would be nearly equal and opposite, and that the central point of the rod joining the two radii would describe a line nearly straight. Hence was originated the simple and beautiful parallel motion. (Fig. 53.)

Watt's earlier engines were single-acting, in which the steam effects work only whilst acting upon one side of the piston—(see fig. 54)—the action being that there are three valves, namely, the steam valve communicating between the boiler and the cylinder, the eduction or exhaust valve communicating between the cylinder and the condenser, and the equilibrium valve which allows free communication between both sides of the piston. During the descending stroke of the piston the steam valve is open, admitting steam from the boiler to the top of the piston, the exhaust valve is open, allowing discharge of exhaust steam from below the piston into the condenser, and the equilibrium valve is closed, preventing communication between the two sides of the piston. During the upstroke of the piston the exhaust valve is closed, shutting off communication with the condenser, the steam valve is closed, shutting off communication with the boiler, and the equilibrium valve is open, allowing the steam within the cylinder to have free access to both sides of the piston, the steam doing no work at all—it cannot, being on both sides.

Some years ago one of the examiners in those days for the Science and Art Department mentioned to the writer that a very large proportion of engineering students who came up for examination had quite a belief that in these

single-acting engines of Watt, the steam, whilst on both sides of the piston, had some influence, which, however, they were not able to explain, in causing movement of the engine.

The later engines of Watt were double-acting (see fig. 55), that is, they had steam doing work on both sides of the piston, and consequently an engine half the size would do the work. There were four valves, namely, one steam valve, affording communication between the boiler and the top of the piston; one exhaust valve, allowing discharge of exhaust from below the piston into the condenser; one steam valve, affording admission of steam from the boiler to the bottom of the piston; and one exhaust valve, allowing discharge of exhaust from the top side of the piston to the condenser. Whichever direction the piston travelled there was one steam valve and one exhaust valve open, and one steam valve and one exhaust valve closed. These engines, both single-acting and double-acting, are shown with steam jackets. Engineering opinion is not unanimously in favour of steam jackets in these days, and probably the large majority of pumping engine cylinders now are clothed, not with a jacket of steam, but simply a jacket of some good non-conductor. The most eminent engineers, however, are decidedly in its favour, and they argue that a steam jacket prevents initial condensation and condensation in the performance of work, and they stipulate, for obtaining the best results, that the water formed in steam jackets should be returned to the boiler. The arguments in favour of steam jacketing may be fairly put as follows:—If we simply coat a cylinder with some non-conducting material, we must remember that steam cannot expand and do work behind a piston without a fall in temperature. The steam entering direct from the boiler will be saturated, and reduction of temperature must necessarily cause partial condensation. Expansion going on, the temperature of the steam will fall below that of the surface surrounding it, and towards the end of the stroke the heated metal will boil off the water deposited, and send it out as steam to the condenser. And by such an action steam will have passed through the cylinder without doing work. A cylinder of metal may be covered with a non-conducting casing, but it remains a large metallic mass, and we can-

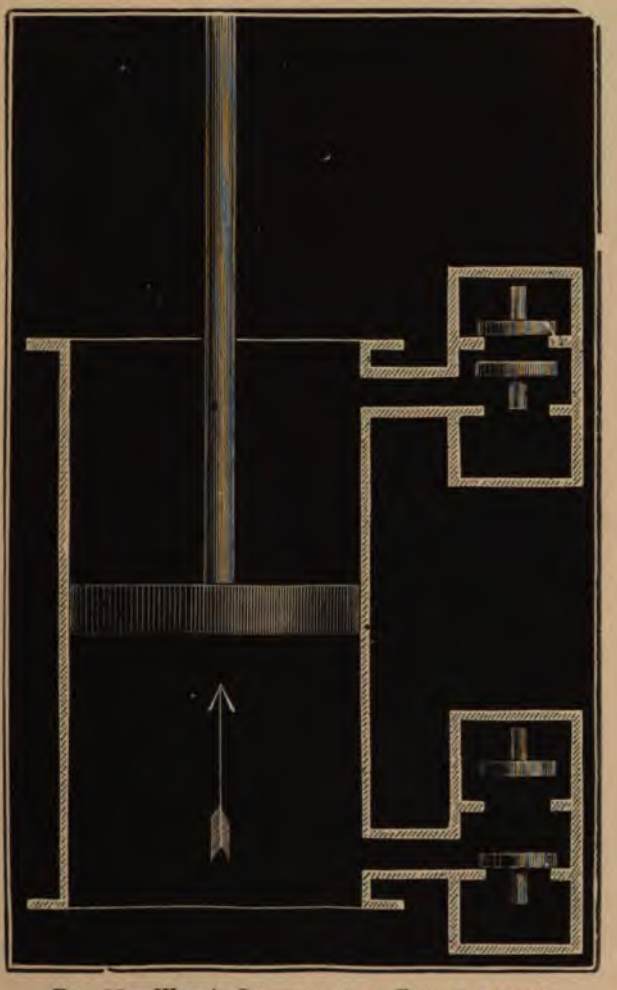


FIG. 55.—WATT'S DOUBLE-ACTING ENGINE MAKING UP-STROKE.

[*To face page* 90.]

not reason about it as if it were not alternately heated and cooled during the working of the engine. And it was this very alternate heating and cooling which Watt was striving to prevent by his separate condenser and steam jacket. The evil effects from a non-steam-jacketed cylinder are that the entering steam is made cold when we want it warm, and the coming steam to the condenser is made warm when we want it cold. There is no known material which is insensible to the action of heat—that is, which cannot be warmed and cooled, and which will not conduct and radiate heat. A cylinder, being made of metal, is peculiarly sensitive to changes of temperature. The reasonable course, therefore, if we wish to use steam in the cylinder under the most advantageous circumstances, is to enclose the cylinder all round the barrel, and at the ends as well, in a hot envelope, which may serve to maintain its temperature at a high level, and supply the heat which is otherwise escaping. We must remember that no non-conducting material, however effective, can do anything in the way of supplying heat to the steam to take the place of any heat that the steam may lose. Some exceedingly good results have been obtained by employing a steam jacket completely enveloping the cylinder, and also having outside a covering of some good non-conducting substance. Under such circumstances, and using steam expansively, a diagram has been obtained approaching theoretic accuracy. Such facts speak volumes. One writer estimates the saving with steam jackets as amounting to 6 per cent. But whatever difference of opinion there may be now, Watt had no doubt at all that steam-jacketing was an improvement; and in this article, at any rate, we ask for no higher authority, especially as even now the cylinders of pumping engines are more frequently steam-jacketed than any other.

One of the most important—if really there is any difference in the importance of Watt's inventions—was the use of expansion of steam. He was at great pains to show the effectiveness and economy of this, and constructed a practical diagram which is as useful now as then. Most of us now understand and believe in the advantages of expansion, but collieries are not the places

where it is most availed of, and not by any means used to the extent it might be. An engine which has no expansion discharges into the air or the condenser, as the case may be, two cylinders full of steam which has done no work at all, and this ought not to be. In 1776 Watt made experiments on the expansion of steam, and he was evidently in no hurry to come to a final conclusion on the subject, as he only patented the improvement six years later. A remarkable feature of Watt's whole career was that he never hurried anything, and although often struggling with weak health and encountering difficulties which would have entirely broken the spirit of most men, he never grew weary of his work. In his specification he said, My new improvement in steam or fire engines consists in admitting steam into the cylinders or steam vessels of the engine only during some part of the descent or ascent of the piston, and using the elastic forces wherewith the steam expands itself in proceeding to occupy larger spaces as the acting powers on the piston through the other parts or portions of the length of the stroke. Fig. 56 gives an idea of the diagram of energy with which this specification was accomplished. The available length of the cylinder—that is, the piston stroke—is divided into twenty equal parts, numbered, and steam is supposed to be cut off at one-fourth, that is, when the piston has travelled over five of these divisions. The lines representing pressures, drawn at right angles to the lines representing length, have ten equal divisions. At division 5, the point of cut off, the full pressure is 10; at division 10, the pressure has fallen to 5; at division 15, it has fallen to $3\frac{1}{2}$; and at division 20, being the end, it has fallen to $2\frac{1}{2}$. The area enclosed to division 5, during which the pressure is maintained from the boiler, represents the work done before steam is cut off, and the area beyond this enclosed by the remainder of the diagram shows the work gained that is performed by expansion. And it is easy to prove graphically from this figure and these areas, that although only one-quarter of the steam needed to fill the cylinder is employed, the effect produced is equal to more than half the effect which would have been produced by one whole cylinder full of steam. And in this manner Watt showed, one hundred years ago exactly, as clearly as we can now,

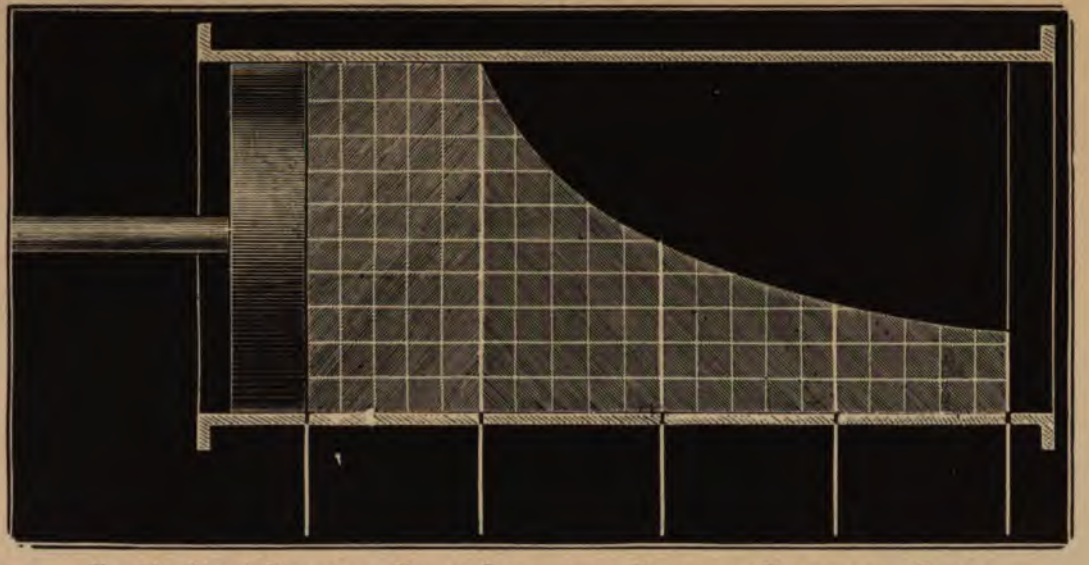


FIG. 56.—WATT'S DIAGRAM OF ENERGY ILLUSTRATING ECONOMY OF EXPANSION OF STEAM.

[*To face page* 92.]

the economy of expansion. Steam in the cylinder may be used in any one of four ways, namely:—1. Non-condensing and non-expansive. 2. Condensing and non-expansive. 3. Non-condensing and expansive. 4. Condensing and expansive.

Colliery winding engines are in too many cases worked without condensation and without expansion; and the true plan to lessen the enormous wastefulness of this arrangement is to have the pressure as high as possible, because whatever the pressure, that from zero to something above the atmospheric line sufficient to overcome back pressure and allow for engine resistance is lost. Some winding engines, most hauling engines, and a considerable number of pumping and fan engines are of the second class, and work non-condensing, but make use of expansion, and as is shown by Watt's diagram of energy, these effect a saving just to the extent that expansion is utilised. But such expansion is extremely limited, unless the initial pressure be very high. The terminal pressure must exceed the atmospheric line by sufficient to overcome the inevitable back pressure. Such terminal pressure can hardly be less than 18 pounds absolute, and to have a cut-off at one-fifth, expanding five times, an initial pressure of 90 pounds would be required. There are not many engines of the third class working condensing and non-expansive, but such as do work on these lines will do the same work with a pressure equal to the atmosphere that non-condensing engines would with 15 or 20 pounds. The fourth class, known as condensing and expansive, Watt's type of engine, and the plan on which all good pumping engines work, give us the maximum efficiency of steam, and when the pressure of steam is low the condensation principle becomes an absolute duty, whilst with high pressure expansion avoids enormous waste. Let us compare the first and last classes with engines of the same dimensions, both 24 inch cylinder and 6 feet stroke, in the one case working non-condensing and non-expansive, and in the other condensing and expansive, both having steam at 60 pounds absolute, and in the latter case expanding 12 times.

The former engine will afford, say a pressure of 60 — 15 = 45 pounds throughout the stroke, whilst the latter gives

an average pressure of about 17 pounds, allowing nothing in either case for back pressures or resistances.

The amounts of steam used will be as 12 to 1, and the power obtained 45 and 17, showing a gain for the condensing and expansive principle of nearly 5 to 1. And with lower pressure in the former case, or a greater ratio of expansion in the latter, the gain increases. And yet in these latter days able pens argue the question, Is expansion gain? and answer it to their own satisfaction in the negative.

Others again, somewhat more reasonably, say If you use steam expansively, you want a larger engine to do the same work. That is so, and if an existing engine is only capable, with the highest steam pressure it can bear, of performing the work allotted to it, expansion cannot be applied. But in designing new engines we can make them large enough, and the larger engine only represents an increased first cost, whereas expansion of steam represents an economy in consumption of fuel for ever, and enables the production of a superior vacuum, of working condensing, and a freer discharge, because there is less back pressure in working non-condensing.

We have not tried in this brief article on Watt to sketch his life and character, or even his work. Our effort has been simply to point out the important influence his genius had in making pumping appliances what they are, and have endeavoured to make such of his contrivances as really are identified with the gradual improvement of the pumping engine clear. And our so doing better fits us for dealing with one or two of the pumping engines and their arrangements now in use, commencing with the once universal and still extensively used and deservedly popular Cornish pumping engine, and pump appliances in connection therewith.

CHAPTER XI.

PUMPING ENGINES AND APPLIANCES.— CORNISH PUMPING ENGINES AND PITWORK.

Engineering in Cornwall—The Cornish Boiler—The Lancashire Boiler—General Principles of Watt's Pumping Engine, Single-acting—William Howe, of Clay Cross—The Pumping Engine at Clay Cross—Cornish Pumping Engines without Circular Motion compared with the Fly-wheel Pumping Engine—Rule to ascertain the Quantity of Water required for Condensation—Table of total Heat of Steam—Pressure in pounds per Square Inch, and Volume compared with Water—The Cornish Bull Engine—Its Advantages over the ordinary Single-acting Cornish Engine—The supposed High Duty from Pumping Engines in Cornwall—Lean's *Reporter*—How Expansion is effected in Cornish Engines—Pumping Engines at Waterworks—Speed of Pumping Engines—Cornish Engine at the Astley and Tyldesley Collieries—Advantages of having the Beam below the Engine—Specification of a Double-acting Upright Condensing Pumping Engine on the Cornish Principle.

The county of Cornwall has of late years fallen from its high estate, but a few generations ago it occupied a foremost position in matters of engineering, and gave its name to a notable class of engine and an equally notable class of boiler. The Cornish boiler was the first really successful attempt to introduce a steam generator which should be strong, so as to be capable of resisting high pressure; economical, so as to give the maximum of power with the minimum of fuel, and a rapid generator of steam, to enable the most work to be accomplished with the fewest boilers. And although the Cornish boiler, pure and simple, is not so generally used now as formerly, an improved type of that boiler—because the Lancashire boiler with two flues is practically a two-flued Cornish boiler—is almost universally applied to all modern col-

lieries. The Lancashire boiler has been dealt with at considerable length in chapters xiii., xiv., xv. of Volume I. This chapter we propose to devote to the Cornish pumping engine.

The general principle of this engine is now as in Watt's days, who gave it to us, namely, a single-acting beam engine with the pumps and rods attached to one end of the beam, and the piston and rod attached to the opposite end of the beam. The engine is single-acting—that is, steam is only admitted from the boiler to the cylinder, and only does work upon the piston during the stroke in one direction of the piston, namely, the downward stroke, and this draws the pump rods up. During the down stroke of this piston there is a double influence on the piston, namely, the steam pressure above and the vacuum from the condenser below. During the upward stroke of the piston the condition of things is changed, the steam valve is closed, and thereby shuts off communication with the boiler, the exhaust valve is closed and shuts off communication with the condenser. The equilibrium valve, which opens a communication between the top and bottom of the plate, is opened, and the steam has free course to take any position in the cylinder, and the pressures acting equally on both sides of the piston balance each other, and no work is done. There is no effect, therefore, either from steam pressure or vacuum during the upward stroke of the piston, and we must look elsewhere for the cause producing the upward movement. This is found at the other end of the beam, where the pump rods are made sufficiently heavy to overcome the weight of the water column to be raised, the weight of the piston and rod, and a balance to overcome frictional resistances. And in this way in the single-acting Cornish pumping engine the work goes on, the downward stroke of the piston being performed under the combined influence of steam and vacuum, and the upward stroke by the influence of the descending pump rods.

In our dealings with pumping engines and appliances we propose to treat of actual examples, and as a beginning we shall throw ourselves upon the indulgence of the Clay Cross authorities, to whose generosity we were indebted for information as to screening appliances dealt with in

Chapter xii. Volume I., and propose to make reference to their massive Cornish engine.

This excellent example of pumping machinery was designed, constructed, and erected by Mr. William Howe, now deceased, than whom no man occupied a more distinguished position in connection with colliery engineering, or did more for its development and improvement. Mr. Howe's description of the Clay Cross pumping engine is in the *Transactions* of the Mechanical Engineers, and is the very best description, illustrated and otherwise, of a Cornish pumping engine that the writer has ever seen. Hence it forms the basis of this article.

In all matters appertaining to practical engineering Mr. Howe was one of the giants of his time. Commencing work at thirteen, he was a workman all his life, the grade of his occupation constantly advancing. In 1842 he introduced the valve gear known as the link motion, the importance of which was shown in its universal application to locomotives. In 1846 his distinguished friend and master, George Stephenson, appointed him engineer at Clay Cross Collieries, and for a quarter of a century Mr. Howe found a congenial sphere of labour. The great love of his life was still his link motion, which he applied to winding engines, and obtained for it a success equal to that already attained in locomotives. Like most working men of his time, his early education was imperfect, but during his early manhood he more than made up for the deficiency of his boyhood in matters of education. No colliery engineer did more—we might almost say that none did so much—to introduce new ideas and so indefatigably and successfully work them into practical shape, and some Smiles of the future will impart a useful lesson to the rising youth of England by including William Howe, of Clay Cross, amongst the men who have made themselves. There has been no intention to occupy this unworthy pen in writing a biographical notice. What has been said is to prove, if proof were necessary, that our particulars as to Cornish pumping engines have been taken from a reliable source, and also the writer was anxious to pay a humble tribute to one with whom he had the honour in his later years to have some slight acquaintance.

Fig. 57 gives an elevation of the Clay Cross engine, and explains itself. The cylinder measures 84 in. diameter, and has a working stroke of 10 ft. The upper nozzle contains the regulating valve, the steam valve, and the equilibrium valve—the former and latter being each 12 in. diameter and the steam valve 14 in. The lower nozzle contains the eduction or exhaust valve, which measures 18 in. in diameter. All these valves are double beat and made of gun metal. The top and bottom nozzles are connected with two side pipes, each 12 in. in diameter, through which the steam passes from the top to the under side of the piston, forming a perfect equilibrium. There are two plug rods, one carrying the tappet to shut the steam valve, which may be varied to work to any degree of expansion, and the same plug rod carries a tappet to work the cataract for opening the steam, eduction, and injection valves. The other plug rod carries the tappets to close the eduction, equilibrium, and injection valves, and also another tappet to work another cataract for opening the equilibrium valve. The working of these cataracts is as follows:—They are charged with water; they have each a working barrel with a ram in it, which is placed inside a small circular cistern; each working barrel has only one clack or valve, which opens inwards. The outlet for the water is through a small orifice, the opening of which is regulated by raising or lowering a plug by means of a screw and handle. The speed of the engine is thus regulated by lengthening or shortening the interval between each stroke, so that it may be worked as slowly as one stroke per minute, or as quickly as eight or ten strokes per minute, according to the amount of orifice allowed for the escape of water from cataract cylinders.

The foot-valve between the condenser and the air pump, and the delivery valve between the air pump and the hot well, are india-rubber discs with brass grid faces, with a guard to prevent their rising too high. The injection pipe measures 4 in. in diameter, tapering to 3 in. The water for condensation is kept at a temperature of 50 degs., which is about correct for economical results, and the temperature of the hot well is 113 degs., which, according to Watt's ideas, is about 13 degs. too high. It may be interesting to show here how to arrive

at the actual amount of water required for condensation, assuming the pressure of steam sent into the condenser at about 5 lb. below atmospheric pressure. Its total heat will be 1,140 degs., the temperature of the condensing water being 50 degs., and the temperature of the condenser 113 degs. The water gains 113 − 50 = 63 degs., and the steam loses 1,140 − 113 = 1,027, so that 1,027 ÷ 63 = 16½ lb. of water required for each pound of steam.

At a pressure of 5 lb. below the atmosphere steam is 2,363 times lighter than water. A cylinder 84 in. diameter has an effective area, making requisite deduction for area of piston rod, of about 5,500 sq. in. × 12 = 66,000 and × 10 = 660,000 cubic inches, capacity for a stroke of 10 ft.; 660,000 ÷ 1,728 = 382 cubic feet, and as each cubic foot of water weighs 62½ lb., 382 × 62½ = 23,875 lb. of water. But steam at the pressure given, 5 lb. below the atmosphere, is 2,363 times lighter than water, therefore 23,875 ÷ 2,363 =, without reckoning anything for clearance capacity, about 10 lb. of steam used each stroke; and on the basis of 16½ times as much water as steam, we require 10 × 16½ = 165 lb. of condensing water, or 16½ gallons for each stroke the engine makes.

A simple rule to find amount of water for condensation is as follows:—

1. Find difference in temperature between water for condensation and the condenser.

2. Find difference in heat between steam discharged into the condenser and temperature of condenser.

3. The second result divided by first result shows how many pounds of water are required for each pound of steam.

4. Find capacity of cylinder and the weight of water that would fill it, and divide this by the volume of an equal weight of steam of the pressure given.

5. Multiply this by the third result, and we have the weight of condensing water required each stroke.

The following table shows the total heat of steam and volume compared with water at different pressures from zero, leaving out decimals.

Total heat of steam.	Pressure in lbs. per square in.	Volume compared with water.
1,113	1	20,760
1,120	2	10,798
1,125	3	7,362
1,128	4	5,625
1,131	5	4,559
1,134	6	3,838
1,136	7	3,318
1,137	8	2,923
1,139	9	2,613
1,141	10	2,363
1,142	11	2,159
1,143	12	1,988
1,144	13	1,842
1,146	14	1,716
1,147	15	1,614
1,148	16	1,516
1,149	17	1,435
1,150	18	1,360
1,151	19	1,292
1,152	20	1,231
1,155	25	998
1,158	30	841

Showing that between 10 lb. below the atmosphere and 10 lb. above there is only a difference of 24 degs., or only about 2 per cent., a difference not material in calculations of this kind. Indeed, we might for this purpose almost assume an average total heat of steam discharged to the condenser of about 1,147.

The beam (see figs. 58, 59) is a very fine example of construction, strong and handsome. It is made of wrought iron, the slab on each side having been rolled in one piece, 2 in. thick, 7 ft. deep in the centre, 3½ ft. deep at the ends, and 36½ ft. long, each slab weighing 7½ tons, and the total weight of the beam 33 tons.

The engine is started with high-pressure steam without a vacuum, the steam and exhaust cataract being kept out of action for a few strokes. The regulating valve is opened by its wheel and screw, the exhaust and the injection valves are opened by their handle, and the steam valve is opened by placing the foot in the stirrup on the rod. This enables the engine to make what is technically known as the indoor stroke, which is the down stroke of the piston, and after a few strokes a vacuum is produced, and the engine regulated to the proper length of stroke by the

regulating valve. The cataract is then set at liberty, and the engine goes on its way, and provided the steam pressure remains about the same, will continue working the same length of stroke and the same number of strokes. The full stroke of 10 feet is not regularly made, and the stroke actually made will average about 5 in. less than this, which will not tend in the direction of economising steam. The usual speed is four strokes per minute, which gives an average speed to the piston of 76 ft., the indoor speed being 290 ft. per minute, and the outdoor stroke occupying double the time of the indoor stroke, there being an interval, of course, at the end of indoor stroke and outdoor stroke. A much higher speed, amounting to 400 ft. per minute, with the indoor stroke has been attained, but at such a speed the engine does not work with comfort.

Such, generally, is the Clay Cross pumping engine, and being single-acting, the moving pitwork has to be heavy enough to balance not only the column of water, but also the piston, parallel motions, plug rods, and all the work hanging on the beam inside the engine-house. The moving pit work, &c., on the outer end of the beam weighs a little more than 34 tons, and the weight of the two columns of water is about 24 tons, leaving a balance of more than 10 tons in excess upon the outer end of the beam to overcome the weight of the piston and the work on the inner end of the beam, which amounts to rather more than 7 tons, thereby leaving an excess of weight of about 3 tons to overcome the friction of the pit work, and to give the necessary speed of motion to the water in the rising main. So that for the downward stroke of the pump rods, being the upward stroke of the piston, 31 tons of pump rods just balance the same weight of water columns, and other rising weight, and the balance of 3 tons, being about one-tenth, gives the comparatively slow movement with which the pump rods descend. But a considerably greater margin than this will be required to force the piston down, owing to the higher speed required and the expansion which is usual.

The circumstances have not been favourable for obtaining high economical results with the engine, chiefly because it has been constructed with a view to performing at some future time a much larger amount of work than

has hitherto been placed at its disposal, but it has been presented here as a fair type of the single-acting Cornish pumping engine.

During the discussion on Mr. Howe's paper descriptive of his engine, the question was raised as to whether, in the event of a mis-stroke, a circular-motion engine with a fly-wheel or a Cornish engine was likely to do the most mischief. Mr. Howe's line of argument was that in crank-pumping engines he had seen many serious breakages of the machinery, in consequence of the plunger missing the first part of its stroke, and then suddenly meeting the water in the pump. And in such engines injury from the concussion was heightened by the circumstance that the force of the concussion arose not merely from the momentum of the moving parts, but was further increased by the engine power, in consequence of the steam continuing to act in the cylinder, so that the plunger was driven down upon the water by the full power of the engine. In the Cornish engine, on the other hand, while the concussion was, no doubt, equally severe, so far as it arose from the momentum of the plunger and pump rods, it was not further augmented by any engine power, as the pump rods made the down-stroke from their weight alone, without any aid from the steam.

The argument against Mr. Howe was that, so far from the Cornish engine possessing an advantage over the rotary engine in the respect named, the advantage was on the other side. In consequence of the massiveness and weight of the pump rods and plunger of a Cornish engine, their momentum was far in excess of that in a crank engine. And although in the latter engine the steam was continuing to exert its force in the cylinder during the stroke of the pump, yet the addition of the heavy fly-wheel completely controlled the speed of the engine, and prevented it from running off instantly if ever the pump missed the beginning of its stroke, whereas the Cornish engine went off unrestrained in the outdoor stroke without any provision for checking its motion in the event of an accident. The concussion produced by such an accident would be far greater in the Cornish engine than in a rotary pumping engine with crank and flywheel.

It will probably seem to the general reader that Mr. Howe, good practical engineer that he unquestionably was,

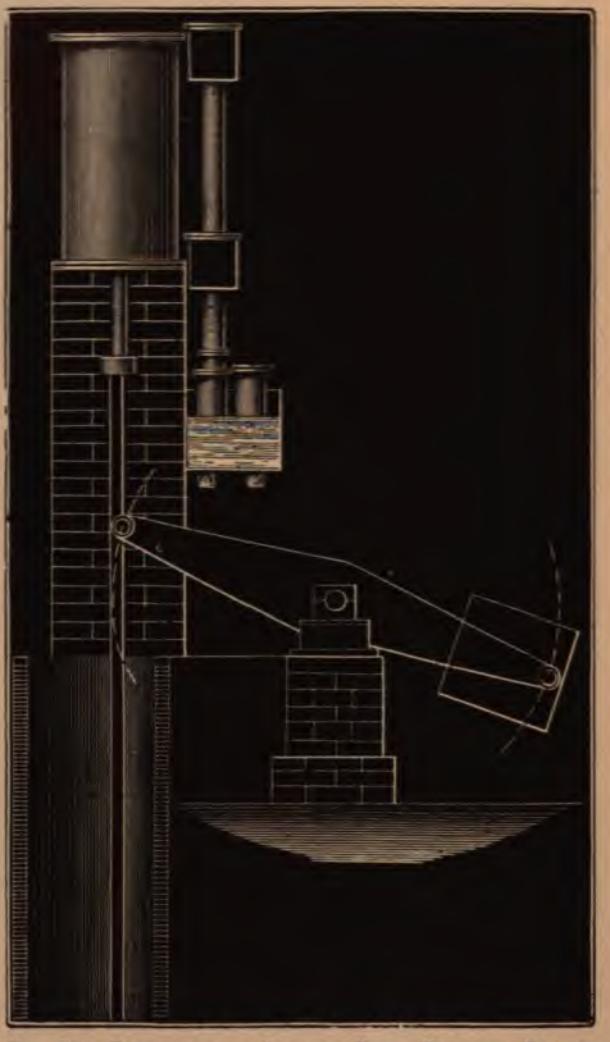


FIG. 60.—ELEVATION OF CORNISH BULL PUMPING ENGINE ARRANGED TO WORK DOUBLE ACTING, AND JUST COMMENCING THE DOWN STROKE.

[*To face page* 103.]

hardly held his own in this argument. Although with a large pumping engine, whether working reciprocating or with circular motion, a mis-stroke is a serious matter, and requires some special appliance to avoid injurious results to machinery.

A single-acting engine on the Cornish principle had some advantage over a pumping engine with crank and flywheel in the fact that no power was required in the Cornish engine for keeping the gearing in motion at each end of the stroke. A certain amount of percussive action was, indeed, necessary to overcome the inertia of the engine at the beginning of the stroke, but, on the other hand, the whole engine was brought to a dead stand at the end of every stroke by the whole effective power being completely absorbed in the work done in pumping. For driving machinery the Cornish engine was admitted to be inapplicable, from the great variation in power throughout the stroke; but for pumping it was effective enough.

It will be observed that in all engines of this construction, with the pump rods at one end of the beam and the piston at the other, the beam will generally be placed at the top of the engine (the foundations for large Cornish engines are well nigh as expensive as the engines themselves), which necessitates a high massive pillar for the beam and entails great friction upon the beam centre, arising from the combined action upon it of power and work. This also necessarily throws an enormous and even dangerous strain upon the beam centre, and it is a little singular that whilst this chapter was being written, the beam centre of one of the largest Cornish pumping engines in England failed at the Peasley Cross and Sherdley Collieries, and had it not been for constant vigilance in the inspection, very disastrous consequences would have resulted.

As a partial remedy for this kind of thing a modified construction of the Cornish pumping engine, known as the Cornish Bull engine, has been introduced and applied with some success. (See fig. 60.) The cylinder is placed at the top and the beam below. The pump rods and piston are both at one end of the beam, and form one continuous line. The engine of the Bull type seems eminently adapted for working double-acting, as all steam engines

should work if practicable, and consequently there is steam pressure and the influence of vacuum during both strokes of the piston. The pump rods in this case should, for the same column of water, be just half the weight needed with single-acting engines. The beam merely transmits power to work the air pump and the valves. A small weight on the beam will balance these, leaving only a little friction on the centres. By this arrangement we make the engine direct-acting, there being no intervention of beam between power and work, we avoid the strong and high pillar for the beam centre, we give the beam less to do, throw less strain upon it, and have less resistance to motion, because the friction on the beam centre is reduced. By having the engine double-acting, a cylinder half the size, or even less, will do the work, and we obtain a more equal exertion of power, and consequently a more equal straining of the engine and all its parts, than in the single-acting Cornish pumping engine.

A double-acting engine will do more than twice the work of a single-acting engine of the same size and weight. The double-acting engine uses steam on both sides the piston, and is generally worked faster than a single-acting engine. Hence, for the same power, it was more economical in first cost than the single-acting engine. And the foundations for such an engine are far away less massive, and consequently less costly, and the beam becomes in itself a structure of less weight and less cost.

Several reasons have been advanced for the enormously high duty which Cornish pumping engines some years ago were supposed to be capable of. The chief reason of all was the healthy rivalry introduced amongst Cornish mine-owners who had pumping engines at work. Mr. Lean, a Cornish engineer, who had already established his claim to rank amongst prominent engineers by his invention of the plunger pump, established Lean's *Reporter* in 1811, and commencing with these engines in the counties of Cornwall and Devon, he gave, month by month, the performances of various engines. And there is no doubt at all that a great deal of beneficial emulation was caused thereby, and the establishment of this *Reporter* was a great incentive to engineers to improve the quality of

their engines. Expansion was carried to its utmost limit, the cut-off in some cases being made at one-tenth, with a result of economy in fuel, accompanied by great wear and tear and breakage of machinery. These chapters have consistently advocated expansion; but, carried too far, we require machinery of enormous size, and exercise a most unequal and injurious strain. This condition of things was not found profitable; therefore, expansion was reduced, and fuel consumption increased. Another reason was the quantity of water was not measured, but the capacity of the ram chambers was taken, and as the stroke actually made was usually considerably less than the stroke of the engine and the stroke of the piston, a higher duty would be assigned than was really obtained.

With Cornish pumping engines the load to be lifted is a constant quantity throughout the stroke, and the possibility of expanding the steam at all on the piston is due to the fact that the load is a mass of matter to which momentum can be imparted, and the expansive force of the steam can be utilised by changing the condition of the mass from a state of rest to a condition of quick motion, the momentum thus stored up in the mass being expended during the latter portion of the stroke in maintaining the motion after the steam pressure has become less than sufficient to support the load. When the stroke begins the power is greater than the work; when the stroke is about ending the work is greater than the power, but the momentum of the moving parts provides the balance and continues the motion till work just balances power and momentum.

With Cornish engines used at waterworks, where there are no long ranges of heavy pump rods to deal with, the speed attained is much higher than at collieries. In such cases the indoor stroke will be performed at a mean velocity of 600 feet per minute. When the steam is cut off at one-fourth, which is found with Cornish engines about the most effective point of cut-off, a 10-ft. stroke will be performed in one second; whereas for mining operations such a stroke would probably occupy two or two and a-half seconds. The best results also have been obtained with Cornish engines working at moderate pressures, such as about 16 lb. per square inch, and with this pressure and

cutting off at one-fourth, no difficulty has been experienced in obtaining 27 inches of vacuum.

In the Clay Cross pumping engine the pressure of steam admitted to the cylinder was only about 6 lb. or 8 lb. We have stated that in the Cornish engine, taken as an example, the water columns were 24 tons, and that the descending pump rods were heavy enough to overcome this; also 7 tons, being weight of piston, &c., at the opposite end of the beam, and a surplus of 3 tons, being one-eighth, to overcome resistances and set the machinery in motion. But as the descent of the piston is made in much less time than the descent of the pump-rods, more margin of power will be required on the piston.

A fair rule, allowing sufficient margin, would seem to work out as follows:—The area of the cylinder in square inches multiplied by the pressure resulting from steam and vacuum in pounds per square inch should be equal to the weight resisting the downward motion of the piston and allow one-half for resistances. That is, supposing, as in this case, the net weight to be raised is 27 tons of pump rods, we should be able to put an average power on the piston during its downward stroke of $27 + 13\frac{1}{2} = 40\frac{1}{2}$ tons. This is for a single-acting engine; and if working double-acting, then we should require a capability of exerting a power of about 20 tons in both directions.

It will be seen from the Clay Cross engine that, calculated in this way, a very slight pressure would deal with the weight to be raised—namely, 27 tons net = 60,480 lb. A cylinder 84 in. diameter will have an area of 5,500 square inches, making deduction for piston rod, and on this area an effective pressure of 11 lb. absolute would just balance the load. And our margin of one-half for resistances would be fulfilled by a total effective pressure of $16\frac{1}{2}$ lb. absolute, being little more than atmospheric pressure. But the Clay Cross engine does more than we have stated. A column of water 160 ft. vertical and 18 in. diameter is raised by a bucket pump during the up stroke of the pump rods. This additional weight of 8 tons of water has to be added to the weight to be raised by the descent of the piston—$27 + 8 = 35 + 17\frac{1}{2} = 52\frac{1}{2}$ tons, the gross power required upon the piston during its downward stroke. This will add about one-fourth to the aver-

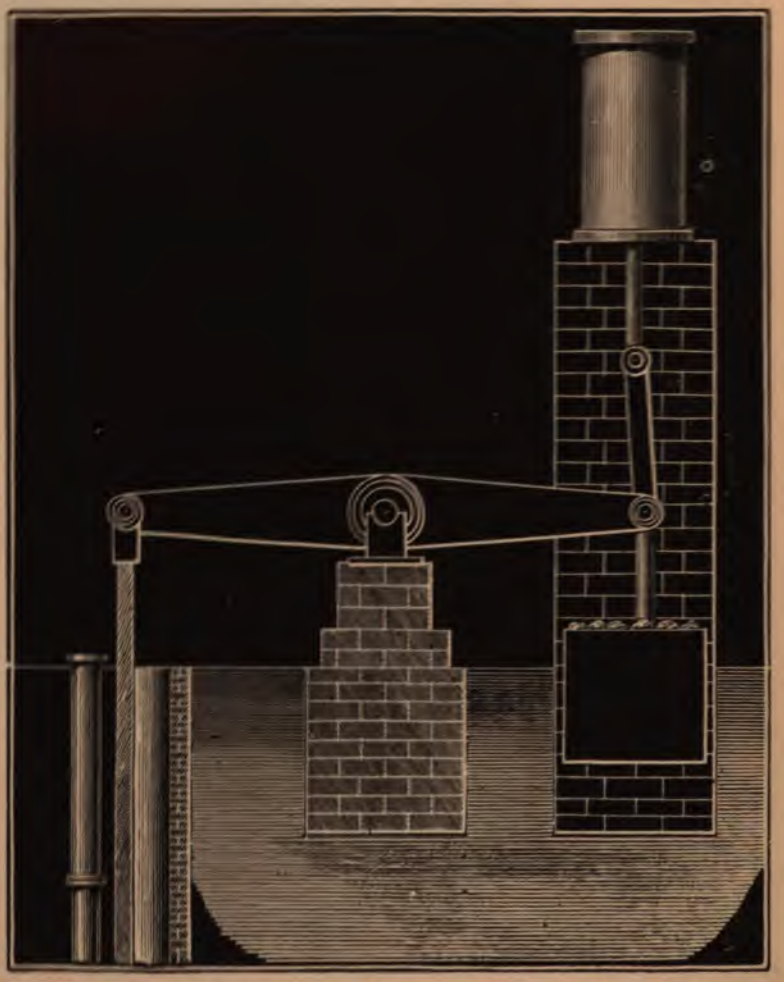


FIG. 61.—CORNISH PUMPING ENGINE, DOUBLE-ACTING, WITH BEAM BELOW AND CYLINDER OVER THE PIT.

[*To face page* 107.]

age pressure required, which now amounts to 20 lb. absolute. The pressures, as shown upon diagrams taken from the engine, give a pound or two less than this, but they are sufficiently near to show the practical accuracy of the principle of the rule, and everybody is agreed that all engines should be more than equal to the largest amount of work they will be called upon to perform.

The writer as yet sees no reason to alter his general and easily understood rule applying to winding engines, hauling engines, fan engines, and pumping engines, viz., to make the power capable of being exerted one-half greater than the net load. That is if the actual amount of useful work to be performed = 2, then the actual power which the engine can exert should = 3.

It is not easy to fix the speed of Cornish pumping engines. Something has been said about speeds really obtained at collieries and waterworks respectively. A good speed for water in pipes has been found at 200 ft. per minute; and as pipes attached to pumps do not usually differ much in size from the plungers or buckets to which they are connected, we may fairly fix upon 200 ft. per minute as an average speed which should not be exceeded.

Fig. 60 illustrates a Bull engine, in which the beam is kept well down, and a high pillar for it to rest upon is avoided. We can keep the beam down and avoid the high pillar in another way. We may have the cylinder above the beam, and at the opposite end from the pump rods, and not only avoid the high pillar, but, what is even more important, we have practically nothing standing over the pit, and the bank is kept clear, thus facilitating work when the pit is used for winding as well as for pumping.

But however we may have the arrangement, if the piston and pump are at opposite ends of the beam, the power and weight oppose each other, or rather concentrate upon the beam centre, causing great strain and considerable friction, which the Bull engine in fig. 61 avoids.

By the kindness of Mr. G. H. Peace, of the Astley and Tyldesley Collieries, the writer has had facilities for obtaining particulars of the double-acting Cornish pumping engine shown in fig. 61. The pit at which this engine is

stationed is used for winding coals as well as for pumping water, and the arrangement whereby the massive beam is kept well down is advantageous for the foundations, and the cylinder being away from the pit allows the engine house to be erected so as to cause no inconvenience to banking operations. The engine has a cylinder 50 in. diameter, and a stroke of 9 ft., and is condensing and double-acting. The available pressure of steam in the engine-house is 50 lb., and the effective vacuum obtained is over 10 lb. The water is raised a little over 110 yards by a bucket pump, and forced the remainder of the distance to the surface by a plunger pump working a lift of another 110 yards. The total height to which the water is raised is about 220 yards, and the diameter of each pump is 18 in., so that virtually the ascent and descent of the piston each raise a column of water 110 yards in height and 18 in. diameter. We can easily ascertain from the facts before us what average effective pressure is required upon the piston. A pump 18 in. diameter will have 254 sq. in., and a column 110 yards = 330 ft. will exert a pressure per square inch = 330 × 15 = 4,950 ÷ 34 = 145½ lb. × 254·4 = a total pressure on the pump of 37,015 lb. The cylinder is 50 in. diameter = 1,950 square inches area, allowing for the piston-rod. Then 37,015 ÷ 1,950 = very nearly 20 lb. of pressure and vacuum. Deducting 10 lb. for vacuum would only leave 10 lb. average effective steam pressure to be provided. But to overcome frictional resistances we should require, not 20 lb. pressure and vacuum, but 30 lb. pressure and vacuum, and as we cannot add much to the vacuum, the difference must be added as steam pressure, showing the average effective steam pressure to be about 20 lb. per square inch on the piston. This, of course, with an available pressure in the engine-house of 50 lb., is easily obtainable. The usual speed at which the engine works does not exceed three strokes per minute, but if the work to be done were greater it would give good results at more than double that speed. The down stroke of the piston raises the water in the bucket pump, and the up stroke in the piston raises the water in the plunger pump. The balance-box at the lower end of the piston rod is balanced, so that the work is equal in whichever direction the piston is

moved. And let us see how this balancing has to be effected. When the piston descends the pump rods rise, and the bucket pump raises the lower column, and the absolute weight being raised is 110 yards of water in the lower lift and 110 yards of rods in the higher lift, because the space occupied by rods in the open or lower lift will not materially differ from the water which these rods take the place of. When the piston ascends the rods descend, and the higher column of water rises, the weight raised being 110 yards of water—110 yards of rods. To effect an equilibrium, therefore, the weight in the balance box must equal half the higher range of pump rods. Any excess in weight over the column of water which the open lift rods have will probably be balanced by the piston and rod and links attached to balance-box end of beam. This pumping engine will raise as nearly as possible 11 gallons of water for each foot of stroke, representing 99 or, say, 100 gallons for each 9 ft. stroke. The work in raising 100 gallons = 1,000 pounds of water 220 yards = 660 feet in one minute = 1,000 × 660 = 660,000 units of work ÷ 33,000 = 20 horse power. This is useful horse power exerted per stroke, and the whole of this useful power is utilised in raising water. Probably the actual power required to overcome the frictional resistances would require the addition of at least one-half, and the total horse-power exerted each stroke be 30. So that this last pumping engine which we have illustrated does not at its present usual working speed probably show an indicated power of more than 90 for three strokes per minute; but if the need ever arose, it could without danger develope several hundred horse-power. Plenty of power is an excellent fault in a pumping engine.

We conclude this chapter with a specification, which, at this point, is interesting as furnishing working particulars of a moderate-sized pumping engine designed within the last few years, and now working with good effect.

SPECIFICATION OF A DOUBLE-ACTING UPRIGHT CONDENSING PUMPING ENGINE ON THE CORNISH PRINCIPLE.

Cylinder.—The cylinder to be 36 in. diameter, and work a stroke of 8 ft.; to be truly bored throughout, and faced at both ends, and to be 1½ in. thick when bored; to be provided with a suitable bottom, prepared with stuffing box and gland, fitted with brass bush and washer, bored to fit the piston rod, also with a cover properly faced and fitted to the cylinder; the cylinder bottom and cover to be secured to the cylinder by turned bolts of suitable size and number; the upper steam branch to be cast on the cylinder, and the lower one on the cylinder bottom, and both to be faced so as to fit the valve boxes.

Piston.—The piston to be of cast iron, of approved construction; to be turned to fit the cylinder, and fitted with three cast-iron piston rings, each measuring 1½ in. square, and fitting in separate grooves, and bored and screwed to fit the piston rod, and be firmly secured thereto, by being riveted behind as well as screwed into it.

Piston Rod.—The piston rod to be 6 in. diameter; to be made of the best scrap iron, one end turned and screwed into the piston and riveted behind, and the other end turned and fitted into the crosshead, and firmly secured with cotters.

Crosshead.—The crosshead to be of wrought iron, bored to receive the piston rod, and the rod for supporting the balance box, and turned to receive the ends of the links to connect it with the beam.

Main Beam.—The main beam to be made in two parts, secured together by bolts and distant pieces; to consist of two strong wrought-iron plate girders, fitted with cast-iron bosses, which are to be bored out to receive the centres; the beam to be about 30 ft. long from piston rod centre to the pump rod centre, and to be 42 in. deep in the middle, and to be made from plates ⅝ in. thick, to be fitted at the outer end with a centre for working a pump in the pit.

Beam Centres.—All the beam centres to be of hammered scrap iron; to be turned and fitted into the beams, and secured to them by wrought-iron keys; the necks for

the main centre to be 7 in. diameter and 10½ in. long—those for the piston rod centre and the centre at the outer end to be 5 in. diameter and 7½ in. long, and those for the air-pump to be 3½ in. diameter and 5¼ in. long.

Pedestals.—The main centre of the beam to be supported by raised pedestals, having brass steps and wrought iron bolts and nuts; these pedestals to be secured to the stonework by means of suitable plates, bolted to the same; the plates to be planed to receive the pedestals.

Slide Bars.—The slide bars to be of cast iron, planed from end to end to receive the side blocks, and to be secured to the stonework so that the slides may work truly in them.

Air Pump Links.—The main beam to be connected with the crosshead by means of two wrought iron links; these links to be about 4 ft. long from centre to centre, and to be fitted with brass steps and wrought iron gibs and cotters.

Valve Boxes.—Each valve box to be of cast iron, made suitable to contain two brass Cornish valves of the following sizes—viz., steam valves 8 in. diameter and exhaust valves 9 in. diameter; all the valves to be truly faced, bored and ground so as to be steam tight; the valve seats to be secured to their places by means of cross bars and bolts; the valve boxes to be fitted with all necessary covers and stuffing boxes, bushed with brass and bored to fit the valve spindles, the valve spindles to be of brass, 1¼ in. diameter, turned and fitted to the valves; the valve boxes to be bored and planed where necessary, and secured to the branches on the cylinder and bottom by bolts and nuts of ample number and strength; they must also be prepared to receive the columns.

Columns.—The columns to connect top and bottom valve boxes to be of cast iron, 9 in. diameter inside—one of them to form the steam pipe and the other the exhaust pipe—and to be fitted with stuffing boxes and glands at the upper valve box, to allow for the expansion of the cylinder, the columns to have preparations cast on them for receiving the pedestals of the hand gear.

Hand Gear.—The hand gear to be worked by plug rods, driven from counter beams placed on the main beams, and to be of the usual kind for such engines; to be

complete in all its parts, with cataract regulator, balance rods, levers and arbors for the efficient working of the engine, all the hand gear above the floor of the engine house to be polished, also all the joints to be steeled or case-hardened.

Air Pump.—The air pump to be of cast iron, 24 in. diameter, and to work a stroke of 4 ft., or to be of equal capacity to these dimensions; to be truly bored throughout, and faced at both ends, and to have a cast iron bucket fitted with an india-rubber valve; the delivery valve to have a cast iron grid seating, fitted with an india-rubber valve, and with a stuffing box and gland bushed with brass and bored out to receive the air pump rod; the rod to be of wrought iron 4 in. diameter, turned and securely fitted to the bucket and cross-head.

Condenser.—The condenser to be of cast iron, to have a capacity of not less than 20 cubic feet, and faced at both ends.

Connection Box.—The air pump and condenser to be fitted to a cast iron connection box, planed to receive them; the connection box to be fitted with a foot valve of brass, to work on a brass facing.

Cold Water Cistern.—No cold water cistern to be supplied.

[NOTE.—Very good results as to vacuum have been obtained in engines without a cold water cistern, and dispensing with such an appliance simplifies the arrangement.]

Hot Water Cistern.—The hot water cistern to be cast on the air pump.

Injection Apparatus.—The injection valve to be worked from the floor of the engine house, by a wheel and screw and to be 4 in. in diameter.

Stop Valves.—Two stop valves to be fitted to the engine, viz., one on each valve box, to be arranged to be worked by screws from the engine house floor, so as to regulate the speed of the engine, or to stop it when required.

Holding Down Bolts.—All the holding down bolts necessary to secure the engine to the stone work to be supplied and fixed, to be made of the best iron with suitable nuts and cotters, and cast iron washer plates.

Flooring Plates.—Two cast iron flooring rafters to extend from the cylinder pillar to the back wall of the engine house, and to be suitable to receive flags.

Balance Box.—A balance box capable of holding a sufficient quantity of furnace slag to give a total weight of 7 tons, inclusive of the box, to be supplied and to be attached to the crosshead at the cylinder end.

Further reference to the Cornish engine will come appropriately in dealing with pumping engines supposed to obviate in their design and construction defects in the Cornish principle; but the Cornish engine was the first pumping engine which did useful work on a large scale, and will for all time be inseparably identified with the glorious name of Watt. Few pumping arrangements, even in modern times, have been able to show better results, and on these grounds we have given it precedence here. Before dealing with any other type of engine, we will speak of pit work connected with pumps.

CHAPTER XII.

PUMPING ENGINES AND APPLIANCES.—PIT WORK OF PUMPS.

Shaft Arrangements of a Plunger Lift—Foundations of Stone and of Timber—Lift resting upon Iron or Timber Horse-trees—Transverse Strength of Timber—Built-up Beams—Ram and Chamber—Clacks and Boxes—Arrangements for packing the Ram and examining the Clacks—Points at which Main and Ordinary Horse-trees should be placed—How Horse-trees are secured in the Pit Shaft, and how Pump Stocks are secured—Table of Strengths of Pipes—Allowance for Wear and Tear and Outward Pressure—Eccentricity of Pipes in Cross Section—Structure of a Pump Stock—Joints of Pump Stocks, how made, and how renewed—Pump Rods, their length and how secured to Plunger—Strength of Pump Rods, and Arrangements of Iron Plates at the Joints—How the Movement of the Rods is guided—Rubbing Boards and Banging Pieces—Pump Clacks, how constructed—The Butterfly Clack—The Single-beat or Mitre Valve—The India-rubber Disc Valve—The Cornish Double-beat Valve—The Advantages of the Cornish Valve, and how it becomes an Equilibrium Valve—Pyramid Valves—Requirements of an efficient Pump Valve—Running Lift when sinking—Bucket Pumps, Sliding Piece and Windbore—The Boot Leg—Pump Rods working within the Stocks—Injurious Action of Joint Bolts on Interior of Stocks—Cases in which a Bucket Pump is advantageous—Pumping Arrangements with the "L" Leg—Difficulties in keeping the Bucket tight—The Height at which the Ram or Bucket should be placed above the Water—Why Water follows the Ram or Bucket—Accidents with Pump Rods and Pumping Cranks—How to have a firm Foundation for the "L" Leg—Pumping Engines with Spur Gearing—Division of a long column into several Lifts, each having a separate Bucket—How the Water Supply for each is regulated—Indicators to show upon the Surface the Level of the Water below.

Fig. 62 shows an arrangement of pit work in which one plunger lift is taken right from the surface to the bottom of the pit, and the shaft is used for pumping exclusively, except perhaps for the raising and lowering of men.

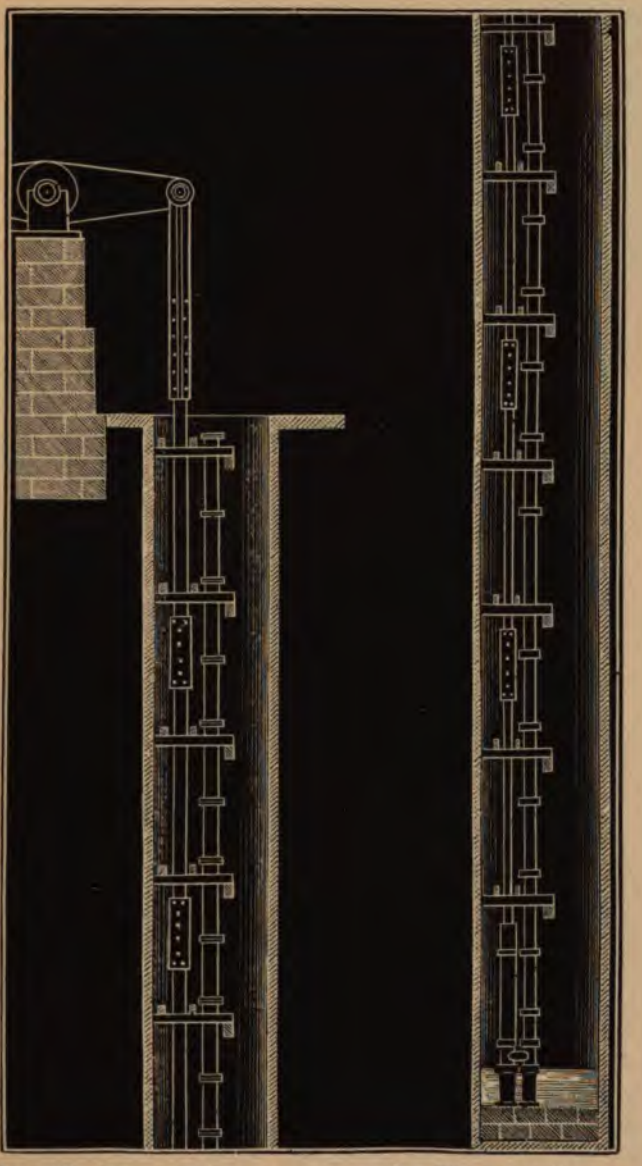


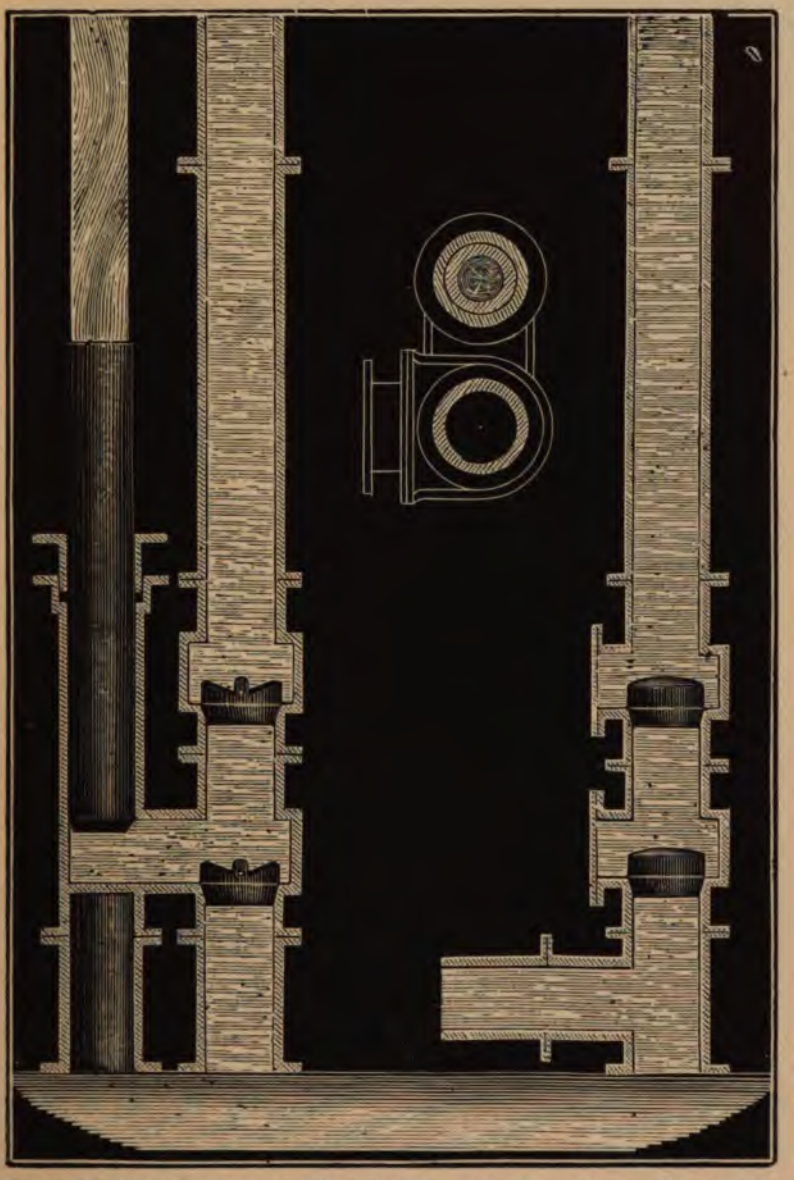
FIG. 62.—SHOWING ARRANGEMENT OF PIT WORK FOR SINGLE PLUNGER LIFT.

[*To face page* 114.]

In such a case we can seat the pump on the bottom, and make the water flow into the pit sump. A substantial foundation will be made of ashlar well bedded upon the pit bottom, and the suction pipes can be brought up sufficiently high to prevent "reck" and dirt getting in and bothering the clacks. The foundation at Clay Cross is a large stone 18 in. thick, and the remainder of the shaft bottom is filled in with hard burnt bricks and Barrow lime, forming a level bottom, so that the sump may be cleaned as easily as possible when required. The advantage of having the pump seated on the pit bottom is that we secure a substantial seating which can hardly move at all, and certainly will not break.

In some cases stone has not been used, and good sound timber has taken its place. Under the circumstances, timber will give good enough results, because being uniformly wet, the timber wears well, but there cannot be that solidity that we obtain with stone, and for heavy pumping machinery firmness at the lower end is desirable. In the event of being undesirable that the shaft bottom should be the reservoir, we can either build up the pump on a pillar and throw the suction pipes out into the lodge formed away from the shaft, or we can seat the pump on horse-trees some distance above. [We have previously in these chapters touched upon the importance of having sufficient lodge-room to hold, if need be, a week's water. And periodically such lodge should be cleaned out to keep the suction pipes free from mud.] The chief point to be guarded against in such a case would be weakness in the support and the supporting horse-trees; whether of wrought-iron girders, cast-iron being objectionable, or timber, we should provide such strength of support that we have strength for all the weight of rods and stocks and water column, and allow the margin of safety 10, so as to provide for any shocks. If timber horse-trees were used it should either be oak or pitch pine, and for such we can go on the basis that a bar 1 in. square and 12 in. between the supports, the safe load is ½ cwt., and whilst the strength increases directly as the breadth and as the square of the depth, it will decrease as the distance between the supports increases. We should aim at a bearing with a short

span and considerable depth. It would not be easy to provide one single beam of sufficient dimensions; accordingly we should build up a beam which, by enabling us to use the best and soundest portions of various logs, would, size for size, give us a stronger built-up beam than if solid. The pump foot should be broad, to fulfil a twofold object, namely, as in columns we get a stronger and firmer structure with a broad base, and the pressure being spread over a larger area, the pump foot would be less likely to sink into the horse-tree if of timber, and the weight would be more distributed—not so much in the middle, which is the weakest place. Having firmly bedded the pump foot we place on these the pump chamber and the clack boxes, as shown in figs. 63, 64 and 65. Good platform accommodation should be provided for packing the plunger and for examining and renewing the clacks, which is best arranged with a recess in the pitshaft, if need be, to enable all work to be performed without the risk attending articles falling down the shaft. The clack doors of a large pump will be of considerable weight, and these should be suspended by chains with tightening screws, so that when the doors are on the chains hang loose, and when the doors have to come off the screws are tightened up, and the doors can be drawn out of the way. Tightening screws are a somewhat slow method, and an even better arrangement has been introduced in which compact and handy little crabs or winches can be made to do this kind of work quickly and easily and safely. From this point we rise above the plunger with the pump rods and above the clack boxes with the pump stocks. The arrangement of the pump stocks and pump rods, whether their line of centres shall be at right angles to the line of the pumping engine beam or continuous with it, must be regulated by the special circumstances. At right angles is probably the most usual method and the best. These horse-trees should be placed at distances of 6 yards, namely, one to each alternate pipe, and about each 48 yards, that is, sixteen stocks, a powerful horse-tree strong enough to bear the weight of all the pipes above it, and the horse-trees should be placed sufficiently far from the pit side to clear the flange of the stocks. These horse-trees are sometimes simply bricked into the brickwork of the pit; and some-



FIGS. 63, 64, & 65.—SHOWING RAM AND CHAMBER, CLACK BOXES, CLACKS, &c., FOR PLUNGER LIFT.

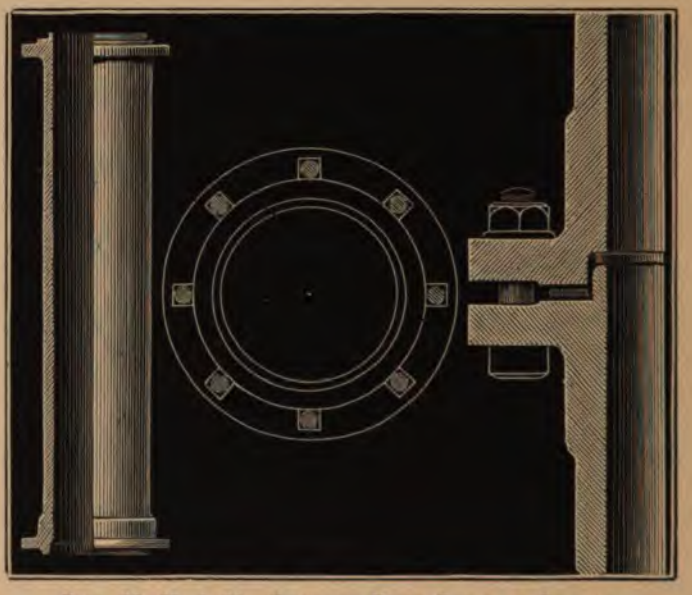
[*To face page* 116.]



times, to avoid this cutting and consequent injury to pit sides, cast-iron boxes are built in as the pit is being bricked and the horse-trees fitted in these boxes. We do not get so firm a job in this way, and the strength of a horse-tree largely depends on its securing at the ends; and perhaps the better way would be to build in the horse-trees as the pit shaft is bricked, thus avoiding cutting, and getting all the firmness required. The stocks, especially in a long column, require steadying, and this is effected by pudlocks on each side, thrown across at each horse-tree, and on these wooden clams, gripping the pump stocks and bolted together, rest. The structure of a pump stock is an important matter, and what we want is a maximum of strength with a minimum of weight. A fair allowance in cast iron used for pipes and cylinders is 1¼ ton = 2,800 lb. per square inch safe working tensile strain [this average tensile safe working strength for cast iron in pipes was laid down to the writer by a very high authority several years ago], and on this calculation the following table comes out:—

STRENGTH OF PIPES.—Safe working pressure in pounds per square inch, reckoning a safe tensile strength of 2,800 lbs. per square inch. Thickness varying from $\frac{1}{8}$ in. to 3 in., and diameter from 3 in. to 36 in.

Thickness in inches.	DIAMETER OF PIPES IN INCHES.																Thickness in inches.
	3	4	5	6	7	8	9	10	11	12	15	18	21	24	30	36	
$\frac{1}{8}$	233	175	140	116	100	87	77	70	63	58	46	39	33	29	23	19	$\frac{1}{8}$
$\frac{1}{4}$	466	350	280	233	200	175	155	140	127	117	93	78	66	58	46	39	$\frac{1}{4}$
$\frac{3}{8}$	700	525	420	350	300	262	233	210	191	175	140	117	100	87	70	58	$\frac{3}{8}$
$\frac{1}{2}$	933	700	560	466	400	350	311	280	255	233	187	156	133	116	93	78	$\frac{1}{2}$
$\frac{5}{8}$	1167	875	700	583	500	437	387	350	318	292	233	195	167	145	117	97	$\frac{5}{8}$
$\frac{3}{4}$	1400	1050	840	700	600	525	466	420	382	350	280	234	200	174	140	117	$\frac{3}{4}$
$\frac{7}{8}$	1633	1225	980	817	700	612	544	490	446	408	327	273	233	203	163	136	$\frac{7}{8}$
1	1867	1400	1120	933	800	700	621	560	509	467	373	312	267	232	187	156	1
$1\frac{1}{4}$	2333	1750	1400	1167	1000	875	777	700	677	583	467	390	333	290	233	195	$1\frac{1}{4}$
$1\frac{1}{2}$	2800	2100	1680	1400	1200	1050	912	840	764	700	560	468	400	348	280	234	$1\frac{1}{2}$
$1\frac{3}{4}$	3267	2450	1960	1633	1400	1225	1087	980	891	817	653	546	467	392	327	273	$1\frac{3}{4}$
2	3733	2800	2240	1867	1600	1400	1245	1120	1019	933	747	624	533	464	373	312	2
$2\frac{1}{2}$	4667	3500	2800	2333	2000	1750	1553	1400	1273	1167	934	780	667	580	467	390	$2\frac{1}{2}$
3	5600	4200	3360	2800	2400	2100	1864	1680	1528	1400	1120	936	800	696	560	468	3



FIGS. 66, 67, & 68.—SHOWING PUMP STOCK IN SECTION, ELEVATION AND PLAN AND THE JOINT.

[*To face page* 119.]

It will be said that some of these thicknesses are absurdly small, or that the pressures are absurdly large, and if we wanted a pipe 18 in. diameter to resist 39 lb. pressure per square inch we should specify for a considerably greater thickness than $\frac{1}{8}$ in., although at the Paris Exhibition of 1867 a pipe was shown of this size and thickness which was none the worse for having resisted an internal pressure of 100 lb. per square inch. It is quite true, however, that in making pipes something else beyond mere internal pressures has to be considered and allowed for. Pipes should have their inner and outer circles concentric, presenting an equal thickness all round, but this they never do, and are often in thickness very eccentric. Some allowance has to be made for this varying thickness, because with a pipe, as with a chain, the reliable strength is in the weakest part. Pipes wear away inside and outside, and however much we may lessen this corrosive influence, an allowance to some extent must be made for wear and tear. Again, pipes may have to resist some outward pressure or be exposed to some rough usage, and must be substantial enough to resist it. On these three grounds there is a minimum thickness that pipes should have, which may be taken as follows, the thickness being given in decimals of an inch:—2 in. diameter, 0·256; 3 in., 0·291; 4 in., 0·320; 5 in., 0·346; 6 in., 0·369; 7 in., 0·391; 8 in., 0·411; 9 in., 0·430; 12 in., 0·481; 18 in., 0·639; 30 in., 0·702; 36 in., 0·760.

The form of a pump stock is worthy of consideration. Generally they are made with thick flanges strengthened with brackets, the body of the pipe close to the flanges made thick, and belts at intervals in the length. This is not the best form of stock, because the varying thickness makes a good casting unlikely. To secure a really well made pipe a uniform thickness of body and flange would be commendable, but we must not forget that flanges undergo a great strain in screwing up the joint, and some metal is taken out of the interior at one end to receive the other pipe. It does seem, therefore, that brackets under the flanges are desirable, and a belt round the pipe at the socket end—and this belt and the flange somewhat thicker than the body of the pipe; figs. 66, 67 and 68 give elevation, section and plan.



Fig. 69.—Elevation of Pump Rod Joint.



Fig. 70.—Section of Pump-Rods and Plates Forming Joint.

[*To face page* 121.]

Sometimes we have plates on two sides only, which is not a good arrangement, and only provides rigidity one way. The better plan is to have a plate on each side, although this involves a great amount of cross-cutting for bolts and consequent weakening of the rods. A good plan would seem to be as shown in figs. 69-70—to have no boring of the rods at all, and pass the bolts along the face of the rods and sink the plates on to the timber, fitting all over two sides and gripping the other two sides. The bolts must also be equal to their work, and as the shearing strength of wrought iron will not differ materially from tensile strain, this is not difficult. When bolts pass through the pump rods they are made square, tightly fitting the holes, which, as has already been stated, should have a slight amount of draw when they pass through the pump rods. Then we want to give the rods a steady movement, and this we accomplish by rubbing boards between the pudlocks, resting on the cross horse-trees. At Clay Cross, the pump rods work through heavy cast iron guides, which are supported on oak buntings resting upon a cross oak bunting, which also acts as a guide for the pump stocks. The part of the pump rods which works through the cast iron guides is covered with hard wood liners or sliding pieces 1½ in. thick, and planed up quite true and parallel, which may be easily replaced when worn. Near the top of the rods a somewhat complicated movement arises from the curved movement of the beam, and the boards must be adapted to this. The pump rods must also be provided with banging pieces, which, in the event of the misstroke and the piston coming against the bottom of the cylinder come upon the main horse-tree with some degree of cushioning, and prevent injury by shock. There are two banging pieces placed at the top and two others placed nearly at the bottom, and are bolted to the pump rods. In ordinary working these banging pieces come in contact with nothing, but strong horse-trees are so arranged that should the rods descend too far the whole mass is supported by the banging pieces. This arrangement of banging pieces can be extended, so that in the not impossible event of the pump rods breaking, the lower portion is suspended safely, and the plunger cannot come destructively down upon the pump foot.

We now retrace our steps somewhat, and refer back to the pump end of the system. The clacks shown in figs. 63, 64 and 65 are supposed to be of brass, and with wrought iron lids faced with leather, and, in fact, of the ordinary butterfly construction. This is the usual type of valves for pumps at collieries, and the reason for their adoption was their simplicity of construction—easily made by the somewhat rough mechanics most useful for pit work—and they are very generally retained because they give very good results in practice, especially as the speed at which such pumps worked was never very high. (See figs. 71, 72.) But they certainly are not a very correct form of valve.

A single-beat, or mitre valve, somewhat similar to those used for the ordinary boiler lever safety valve, and provided with india-rubber springs to break the shock on rising and ensure their closing quickly, have been successfully applied. (See fig. 73.) And for moderate pressures the india-rubber disc valves, after the manner of those used for air pumps, do well. (See fig. 74.) But the best valve of all for water as for steam is the double-beat valve, fig. 75.

The Cornish double-beat valve is very largely used for steam and for water, and is deservedly popular. It may be used for the water to pass through it from the inside or from the outside, and combines the two great advantages of being approximately an equilibrium valve, therefore moves about easily, and having two circumferential seats, a comparatively small amount of lift affords a very large amount of opening. Indeed, when the lift equals one-eighth of the diameter the circumferential opening of the valve is equal to the area of a pipe similar in diameter. We will just suppose the two arrangements of supply from the inside or from the outside. In either case, of course, with a crown valve, the lower seating is larger than the upper one, and when the steam enters from outside we cannot make the valve perfectly in equilibrium, because we have a larger area presented to downward pressure than upward pressure, and, in addition, the weight of the valve acts downwards. If the steam is supplied from the inside, then we can have area opposed to upward pressure as much greater than the area exposed to downward pressure as



will just make up for the influence of gravitation upon the valve itself, and thus, while closed, we should have a perfectly balanced valve. In either case, when open, the pressures from steam or water will exactly balance each other, and equilibrium will cease to the extent of the valve's own weight, which must act downward. Probably the best arrangement is for the steam or water to enter from the outside, in which case there will be a tendency to keep shut and a slight tendency to close when open. Any departure from perfect equilibrium should be in the direction of closing, not opening. A Cornish valve is approximately an equilibrium valve, because its extensive surface is so presented to pressure in all directions that the opposing pressures balance each other and leave only the comparatively slight weight of the valve itself unbalanced, which, as just explained, may be an advantage rather than otherwise. Such valves are very extensively used at collieries for steam, both in winding and pumping engines, but are not as yet generally adopted for water valves. In the future they will probably come more into use.

A good many years ago valves of a different construction to any of those named came into use. The idea was to afford the maximum area of opening with the minimum of lift, thus diminishing the cause of concussion, and to give durability, which was secured by ease of shutting and opening with the least movement. And all these valves consisted of a number of valves arranged somewhat after the form of a pyramid. Sometimes there were leather clacks opening on hinges, and sometimes india-rubber balls were introduced, each ball falling into a separate conical seating. But all these contrivances seem to possess an injurious amount of complication, and did not come extensively into use. No kind of pump valve will become at all popular unless it combines efficiency and non-liability to get out of order, and if out of order easy to repair.

We have, so far, supposed the pit ready for the pump, and we have placed it in commencing from the bottom, and when this is so the work can be conveniently done without much expense for the mere putting in. But in most cases the pump has to be commenced from the surface and go down with the shaft, and what we term a

running lift becomes necessary. In such a case, if using a Cornish engine with a plunger pump, we should first of all, temporarily seat the pump at as low a point as the water would conveniently allow. And having done so, we attach supplementary rods to the main rods, and these supplementary rods work a bucket in the running lift. This lift is either attached to the horse-trees or suspended by ropes from capstans on the surface. And the pump foot consists of a sliding piece and windbore. (See figs. 76, 77.) The windbore, which is a kind of cylinder having the sliding piece as a piston, is suspended from the surface, and can be run out gradually to the extent of a pump stock length as the pit increases in depth. When there is sufficient depth for another stock the sliding piece is let down and a stock put on either at the top of the range of pump stocks or just above the working barrel. The windbore may be full of holes at the bottom for the admission of water, or have a solid bottom and a branch on the side for the suction. The connection between this branch and any pothole arranged to collect the water for convenience of sinking is often made by a pipe of leather called a boot leg, but the writer obtained equally good results by using light elbow pipes of cast iron.

In using a bucket lift, the rods work within the stocks. (See figs. 78 and 79.) And there are some attendant disadvantages. The rods are concealed and are incapable of inspection. Not only do the bolts and rods sometimes break, but in spite of the rubbing pieces the bolts will wear against the stocks, causing loss of power by friction, and destroying the pipes. Not very long ago a long range of pump stocks had to be entirely renewed, chiefly owing to the channelling inside by the rubbing of the bolts. Of course proper care would avoid anything like so serious a condition of things as this, because the iron bolts can hardly wear upon the iron pipes without making an unpleasant noise, which can be easily detected. And the whole length of pump rods ought to be disconnected and withdrawn during a dry spell each year. At such a time a day, and if need be more, can well be spent examining all the rods and plates and bolts and rubbing pieces and renewing whatever requires renewal. In consequence of the pump rods of a bucket lift working within the column

of water, the descent of the bucket displaces more water below than there is room for above the bucket, and consequently the bucket, although popularly supposed to raise all its water during the up-stroke does actually to some extent act as a plunger and raises some water during its descent.

These bucket lifts avoid the injuriously sudden strains to which plunger pumps are liable, and for the impurities in water inevitable with sinking, do better than plunger pumps possibly could.

The writer had occasion to put in and carry down a pump whilst a pit was being sunk, and used from the surface a single bucket lift worked from an L leg, receiving power from a horizontally geared engine. The idea was to fix as a permanent pumping arrangement when the point was reached at which the pump was to be permanently seated, a double-acting Cornish Bull engine working a plunger, but the temporary appliance did so well, and carried the lift so effectively to a depth of 150 yards and shaped so well afterwards that the more modern and certainly much more expensive plant has not been considered necessary. The plan adopted was that additional stocks were added immediately above the working barrel, and as extra length of pump rods always extended above the surface these could be let down as required. To form a connection between the pump rods and the L leg, and allow the rods to project, if need be, a considerable distance above, the pump rods were gripped by wrought iron plates, securely bolted together, and having a projecting stud on each side. Two stout plates were secured to each side of the L leg, and had eyes which fitted the studs, and compelled the upward and downward movement. No bolts passed through the rods, consequently, lowering the pump rods simply meant unscrewing. As the depth became very great some difficulty was experienced in keeping the bucket tight (see figs. 80 and 81), and it was found, if not desirable, at least effective to make use of leather uniform in thickness and in quality, and to turn the bucket hoops.

The buckets are sometimes made of brass, and the lids of iron faced with leather like those of the clack already shown, and the hole in the bucket rod through which

the hinge pin passes is slightly oblong, to allow the lids to lift a little in opening. The arrangement shows the leather placed on the bucket in the usual manner and covered by the hoop below, by which means it is hoped to prevent the leather from wearing out on one side of the bucket, as sometimes occurs, by the flange on the top of bucket and the hoop on the bottom keeping the bucket in a truly central position in the working barrel, the leather acting solely as the water-tight joint between the flange on the top and the hoop on the bottom of the bucket. The arrangement of pump stocks and joints and means for steadying the stocks were the same as with a plunger pump, and rubbing pieces had to be affixed to the pump rods to prevent their rubbing against the pipes. And to ensure the bucket coming up through the pipes, if needed at any time, the stocks in all cases are larger than the bucket. For the effective working of any pump the plunger or pump should be at as little a vertical height above the water that has to rise to it as possible, and any considerable distance between the clack below the bucket and the bucket at the bottom of its stroke is not beneficial to its working. Tales are told sometimes of the enormous height that pumps will draw, 30 ft. and so on, but the fact is pumps do not draw at all. The pressure of the atmosphere will, acting upon water having no atmospheric or other pressure against it, force water up to a pump 34 ft., in theory. But this is supposing a practical impossibility, namely, a perfect vacuum; 26 in. of vacuum instead of 30 is very fair in practice. And this represents not 34 ft., but 29, and really we can do little good with pumps where the height exceeds 27; and whilst 21 is better, pumps work better and better as this height is reduced.

The old-fashioned L leg pumping arrangement with bucket lifts has done, and is still doing, good work. Sometimes the pump-rods break, because, weight being an important consideration, they are put in too light. Sometimes the rod-bolts break because there is too much play in the holes, or—more often the case—the bolts are made of that abomination, bad iron. Again, the pumping cranks, which give motion through the wooden connecting rods to the L legs break. In one case a pit in sinking

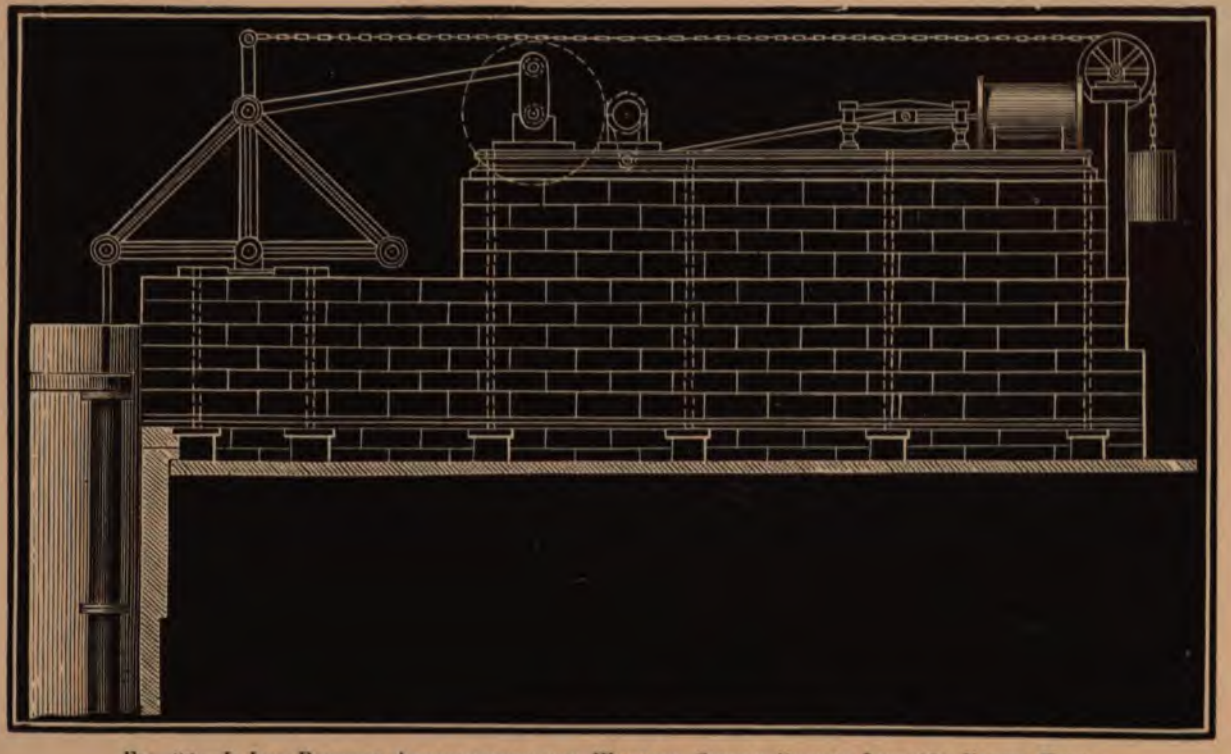


FIG. 82.—L LEG PUMPING ARRANGEMENT FOR WORKING SINGLE BUCKET LIFT 150 YARDS HIGH.

[*To face page* 127.]

broke three of these cranks in three months. They are mostly made of cast iron, and are sure to break sooner or later—often sooner. The clack gets staked either with dirt or a piece of stone or timber, a mis-stroke is made and cast iron cannot stand it. The remedy is wrought iron cranks, either forged in pieces and secured by the crank pin, or, what is better, bent cold under hydraulic pressure, in which case they will never break. With these appliances a firm foundation for the L leg is an essential. If at all loosely placed at the top of a pit on the edge, the pull down when the bucket commences to lift and the throw up when the bucket, commencing its downward stroke, sets against the water, puts the L leg foundation on the move, and mischief will certainly result. In the case which has been referred to a considerable depth of foundation was put in, and by means of old railway metals laid over the hand-holes lengthwise and crosswise of the pillars, the whole weight of the L leg, the spur gearing, and the engine and their respective pillars were thoroughly tied together, and nothing moved. Usually there are two or three separate bucket lifts arranged to divide the column of water and made to balance each other; but with a single bucket lift some other arrangement was needed, and this was done by attaching a chain to the L leg; this chain passed over a pulley, and had suspended a weight equal to the pump rods, so that no work was done during the down stroke, and only the column of water had to be raised during the upstroke. (See fig. 82.) This balancing could, had it been thought necessary, have been applied so as to equalise the work of the upward and downward stroke —that is, taking the total weight to be raised each stroke as represented by columns of water and pump rods, we might make the balance equal to one-half. In the rising main a valve is often placed about 2 in. in diameter, with a pipe leading back to the well from which the pump draws for the purpose—where there is more than one pump—of regulating the supply to each. These valves can be worked by rods from the surface, and floats are also arranged recording on the surface the level of the water below.

CHAPTER XIII.

PUMPING ENGINES AND APPLIANCES.—THE COMPOUND DIFFERENTIAL PUMPING ENGINE.

Mr. Henry Davey, of Leeds—His Efforts to improve Pumping Machinery—Economy in Fuel, in Maintenance, and in Construction—Condensation and Expansion—Double-acting Engines working at a High Speed—Inexpensive Foundations—Defects of the Cornish Pumping Engine—Varying Strain—Irregular Speed—The Differential Valve Gear—Distribution of Steam proportionate to Load—Reverses the Steam when Load is suddenly lost—The Gear is automatic, and the Shocks inevitable with Cornish Engines avoided—Description of the Compound Differential Engine, and Action of its Mechanism—Experiments at Lambton Colliery—Application of the Engine at Waterworks—Figures illustrative of the Differential Gear—Beginning of Stroke—Light Load, early Cut-off—Heavy Load, late Cut-off—End of Engine Stroke—The Compound Differential Engine and the Cornish Engine compared—Expansion in the Cornish Engine—Expansion in the Compound Engine—Application of the Differential Gear to other Engines—Compound Differential Engine underground in South Wales and at Staveley Collieries—The Science and Art Department, South Kensington, and Davey's Compound Engine—Good Results with the Engine above ground and below.

An appliance which, during the past few years, has entered into close competition with the deservedly popular old servant, the Cornish pumping engine, and which appears likely in the not distant future to altogether supersede it, is the compound differential pumping engine with which the name of Mr. Henry Davey, of Leeds, is so honourably associated, and the very earliest opportunity in this chapter is taken of acknowledging the kindness of that eminent engineer in placing the leading facts of the following description at the disposal of the writer. It is hoped this description, together with the eleven accom-

panying illustrations (figs. 83 to 93) will make clear the leading principles of the most important and successful improvements made in pumping machinery in the present generation. Its somewhat peculiar name is derived from its most special and successful feature, a differential arrangement of valve gear which is employed for effecting the distribution of steam. Mr. Davey would seem to have gone a very long way towards perfection in the three great requirements of not only pumping machinery, but machinery of any kind, namely, economy in fuel, economy in maintenance, and economy in construction. Economy in fuel is obtained by being an expansive and condensing engine, on which two principles economy in fuel must depend. The Cornish engine has won its position amongst pumping engines because of its pre-eminent success in this respect. Economy in construction is secured by having a double-acting engine working at a fairly high speed, and the foundations required being of an inexpensive character. Here our old friend, the Cornish engine, appears to less advantage. It is an expensively constructed engine, and the foundations massive and costly. Economy of maintenance is secured by a practically uniform strain, a practically uniform speed, and a contrivance whereby shocks are avoided and the power upon the piston effectively regulated to the resistance to be overcome. The Cornish engine, although perhaps not costly as regards maintenance, experiences anything but a uniform strain, does certainly not give a uniform speed, and has no means of avoiding shocks. The differential valve gear which produces this latter result will be well understood from the figures. It will suffice now to say that in designing the contrivance the aim to be accomplished was to distribute the steam in such a way as to cause no shock or slip in the pumps, and in the event of a sudden loss of load the engine should be safe, and, in fact, that the engine should be self-governing under extreme variations of resistance. The differential valve gear does all this. It admits steam to the engine in proportion to the resistance to be overcome, and in case of a sudden total loss of load, reverses the steam to catch the piston. The distribution of steam, as the figures show, is effected by coupling the motion of the engine with that of a piston having a uniform velocity.

The engine is made to cut off steam by its motion, whilst the uniformly moving subsidiary piston is employed in admitting it. As long as the resistance to the engine is sufficient to prevent its motion becoming relatively equal to that of the subsidiary piston steam is admitted up to the fixed point of cut-off; but should a loss of resistance or a superior pressure of steam cause the engine to acquire a speed relatively greater than the speed of the subsidiary piston, then the motion of the steam valve would be reversed earlier, and the supply of steam would be adjusted to the altered conditions. So perfect is the action of the gear that when properly adjusted the full load may be thrown suddenly off the engine without any injury resulting. The effect of a sudden loss of load is to reverse the action of the valves, and to throw the steam against the motion of the piston, stopping it before the end of the stroke. This kind of thing will occur when a pump rod breaks, or a pump valve has failed, or a pipe has burst. Actual mishaps have occurred in which but for the action of this gear great damage must have been committed. In one case the load was suddenly thrown off the engine when it was running at full speed, by the accidental lifting and tilting over of one of the pump valve seatings, but the engine was instantly checked by the automatic action of the gear, and no more shock was caused to the engine than if the accident had not occurred. In another case the mains at a waterworks burst without causing the slightest damage to the differential engine. We can realise what, in such cases, the probable results would be with the Cornish pumping engine.

The simplest form of this engine has a double-acting cylinder, with the power applied direct to the pumps. The compound differential engine shown in fig. 83 has a pair of horizontal cylinders, the back end of the high pressure cylinder, A, forming the front cover of the low pressure cylinder, B, as shown in the sectional plan, fig. 84. There are two piston rods to the low pressure piston, which pass through tubes cast on the sides of the jacket of the high pressure cylinder, as shown in fig. 84; these two rods, and that of the high pressure cylinder between them, are all fixed to one crosshead, to which is attached the connecting rod, C, for working the pumps, D D, fig.





93. The cylinders are bolted down upon a strong girder bed, E, and the condenser, F, is carried on a separate bed behind the low pressure cylinder, B, the air-pump being worked by a tail rod from the low pressure piston. The differential valve gear, which is the particular feature of the engine, is shown in figs. 86 to 89, and its action illustrated in the diagrams, figs. 90 to 93. These diagrams are intended to show clearly the action of the gear, whilst figs. 86 to 89 show a practical example of its application to a compound engine. The main slide valve, G, fig. 90, is actuated by the piston rod through a lever, H, working on a fixed centre, which reduces the motion to the required extent and reverses its direction. The valve spindle is not coupled direct to this lever, but to an intermediate lever, L, which is joined to the first lever, H, at one end; the other end, M, is joined to the piston rod of a small subsidiary steam cylinder, J, which has a motion independent of the engine cylinder, its slide valve, I, being actuated by a third lever, N, coupled at one end to the intermediate lever, L, and moving on a fixed centre, P, at the other end. The motion of the piston in the subsidiary cylinder, J, is controlled by a cataract cylinder, K, on the same piston rod, by which the motion of this piston is made uniform throughout the stroke, and the regulating plug, Q, can be adjusted to give any desired time for the stroke. The intermediate lever, L, has not any fixed centre of motion, its outer end, M, being jointed to the piston rod of the subsidiary cylinder, J, and the main valve, G, consequently receives a differential motion compounded of the separate motions given to the two ends of the lever, L. If this lever had a fixed centre of motion at the outer end, M, the steam would be cut off in the engine cylinder at a constant point in each stroke, on the closing of the slide valve by the motion derived from the engine piston rod; but inasmuch as the centre of motion of the outer end, M, of the lever shifts in the opposite direction with the movement of the subsidiary piston, J, the position of the cut-off point is shifted, and depends upon the motion of the subsidiary piston at the moment when the slide valve closes. At the beginning of the engine stroke the subsidiary piston is moving in the same direction as the engine piston, as shown by the

arrows in fig. 90, and in the instance of a light load, as shown in fig. 91, the engine piston, having less resistance to encounter, moves off at a higher speed, and sooner overtakes the subsidiary piston moving at a constant speed under the control of the cataract; the closing of the main valve, G, is consequently accelerated, causing an earlier cut-off. But with a heavy load, as in fig. 92, the engine piston encountering greater resistance moves off more slowly, and the subsidiary piston has time consequently to advance further in its stroke before it is overtaken, thus retarding the closing of the main valve, G, and causing it to cut off later. At the end of the engine stroke, fig. 93, the relative positions become reversed from fig. 90, in readiness for the commencement of the return stroke.

Diagrams were taken from engines employed for pumping at the Lambton Colliery, in the county of Durham, during sinking operations. The engine was working at the time without the condenser, because the water was so full of mud that it could not be used with advantage for condensing. There was a much heavier lift on one pumping quadrant than the other; the cut-off was consequently at 47 per cent. of the stroke in the inward stroke, and 60 per cent. of the outward stroke, the change at each successive stroke being made entirely by the automatic action of the differential valve gear. The subsidiary piston, J, fig. 89, being made to move at a uniform velocity by means of the cataract K, the cut-off consequently takes place at the same point in each stroke so long as the engines continue to work at a uniform speed, but if the speed of the engine becomes changed in consequence of a variation in the load—if, for instance, the load is reduced, causing the engine to make its stroke quicker—the subsidiary piston has not time to advance so far in its stroke before the cut-off takes place, and the cut-off is therefore effected sooner, as in fig. 91. On the contrary, if the load be increased, causing the engine stroke to be slower, the additional time allows the subsidiary piston to advance further before the cut-off takes place, and the cut-off is consequently later, as in fig. 92. This adjustment of the cut-off point in accordance with each variation in the load is entirely self-acting, and takes place

instantly, however sudden and extensive the variation of the load on the engine may be. Consequently, the engine is rendered safe in working against the variable loads, as it automatically and instantly varies the distribution of steam with every increase or decrease of the resistance. The action of the differential valve gear is so sensitive and perfect that the load on the engine may be greatly varied whilst in full work without requiring hand control by the stop valve. Engines on this plan may accordingly be employed to pump direct into town mains without the use of stand pipes or balance valves. The force acting on the subsidiary piston, J, fig. 89, is much greater than that required for moving the slide valve, the excess being absorbed in driving the fluid in the cataract cylinder, K, through the small and adjustable aperture, Q, and as the resistance of the fluid increases as the square of the velocity a very small variation only in the speed of the subsidiary piston can be effected by a considerable variation in the force upon it, so that the speed is maintained practically constant for a given adjustment of the cataract plug, Q, although the pressure of steam may vary. The main slide-valve, G, fig. 89, is opened at the beginning of each stroke by the motion of the subsidiary piston, which is controlled by the cataract, and a pause is consequently given at the completion of each single stroke of the engine, which allows time for the pump valves to fall to their seats. Slip in the water is by this means prevented, as well as the shock which occurs when pump valves close under the pressure from a moving plunger. This freedom from shocks on the pumps is an important point, giving safety from accidents such as the bursting of pipes, and at the same time durability of the valves and seats is materially increased. In figs. 83 and 84 are shown the details of the arrangement for communicating the motion of the engine piston to the intermediate lever, L, of the valve gear, fig. 89, by means of the long lever, H, and connecting-rod, R, figs. 85 and 89, the lever, H, being itself actuated by a connecting-rod from the engine cross-head, as indicated in fig. 83. An independent steam starting or pausing cylinder is provided at S, fig. 85, the piston rod of which carries a rack gearing into a pinion on one end of a tubular shaft, T, fig. 89. The

other end of the shaft being made with a screw thread, its rotation traverses the outer end, P, of the lever, N, of the valve gear, and thereby opens the small slide-valve, I, of the subsidiary cylinder, J. The slide-valve of the pausing cylinder, S, is moved by tappets by means of the lever, U, fig. 83, which is actuated by the same lever, H, that works the inner end of the intermediate lever, L, of the valve gear. The pausing cylinder is itself also controlled by a cataract cylinder, V, on the same piston rod, and the length of pause after each stroke of the engine is consequently determined jointly by the two cataracts, V and K. The first regulates the time of opening the small slide-valve, I, for starting the subsidiary piston, J; after which this piston, under the control of the other cataract, K, has to travel a sufficient distance for opening the main slide-valve, G, of the engine. The adjustment of the cataract, K, also determines the mean piston speed or the engine under the normal condition of load and steam pressure.

Fig. 86 gives a longitudinal section through the steam chests and slide valves of the two cylinders, and figs. 87 and 88 are transverse sections of the valves. The slide-valve, G, of the high-pressure cylinder has a couple of narrow ports through the thickness of the metal from end to end, as shown in figs. 86 and 87, the effect of which is that while the engine is pausing at the end of its stroke for the valve to be moved from mid position through the extent of the lap, a communication is established from one side of the piston to the other, so that whatever the amount of clearance space left in front of the piston at the end of the stroke it becomes all filled with steam that has just done its work behind the piston. This prevents the slight loss that would occur in having to fill the whole clearance with full boiler steam at the commencement of the return stroke; the initial steam has now only to raise the pressure in the clearance from the terminal pressure in the high pressure cylinder, instead of from the terminal pressure in the low-pressure cylinder.

A double-beat valve, W (fig. 86), is provided in the steam pipe, and is worked off the main valve spindle by means of a bell crank lever and the pair of slotted connecting rods, X X. These are fitted with right and left-handed

screws, so as to afford a ready means of adjusting the degree of expansion in the high-pressure cylinder under the normal conditions of the engine, without the use of a back cut-off slide. The main slide-valve, G, is also relieved from working under the full boiler pressure after the steam has been cut off by the double-beat valve, W. The slide valve, Y, of the low-pressure cylinder, figs. 86 and 87, is balanced by means of a steel ring inserted in an annular groove, Z, on the back of the valve, as shown also in the plan, fig. 89. This ring is pressed outwards against the steam chest cover by an india-rubber packing ring compressed beneath it in the groove, and there are also a series of small holes in the bottom of the groove for the admission of the steam pressure behind the packing. In starting the engine, steam is first admitted to the cylinder of the subsidiary piston, which moves forward at a steady uniform pace at the speed allowed by the cataract, and thereby opens the main slide valve, the engine end of the valve lever being for the moment at rest. The engine then commences its motion, and if the load upon it were small in proportion to the pressure of steam on the piston, it would move off with a comparatively high velocity, and would thus more quickly overtake and neutralise the lead which the subsidiary piston had had over it, thereby cutting off the steam at an early point of the stroke. But, on the other hand, if the resistance were great compared with the steam pressure, then the engine would move off more sluggishly, and would be longer in overtaking and neutralising the lead of the subsidiary piston, so that the cut-off in that case would take place much later than in the former instance. If instead of being simultaneous, the two movements imparted to the valve lever had been made to take place in succession, the subsidiary piston having the lead, the main slide valve would always have been opened to the full extent at the commencement of the engine stroke, and would always have been closed at exactly the same point in that stroke, and there would consequently have been no variation in the cut-off to suit different loads. But as the two movements were simultaneous, the travel of the valve gear was a continual gliding motion, differentially compounded of the two

movements, the one given by the independent subsidiary piston being a uniform movement, while the other, being dependent upon the motion of the engine, was a variable one. So long as the motion of the engine continued constant, the relative movements of the engine piston and slide valve would be constant also, but whenever the motion of the engine varied, these relative movements and the consequent point of cut-off would vary accordingly.

The compound differential pumping engine would seem to combine whatever advantages the Cornish engine possesses, and has in addition considerable improvements in which the Cornish engine is found wanting. The Cornish engine is very often a single-acting engine, and when such is the case is an engine performing half work, and requiring the same foundation in extent and cost as if performing work both ways. The Cornish engine, with the exception referred to in a previous chapter, stands over the pit, which is not good for the pit shaft itself nor the engine, and is very inconvenient for work being done about it. The Cornish engine is a single cylinder engine, and in all such the limit of beneficial expansion is soon reached. It depends upon the amount of momentum that can be stored up in the moving mass, and is proportionate to the weight in motion multiplied by the square of the velocity. In order to expand to a great extent in a single cylinder, there must be a great variation between the pressures at the beginning and the end of the stroke, which requires a large amount of momentum to be imparted to the moving mass at the commencement of the stroke. With this condition of things one of two evils is inevitable. Either we must have a very high initial velocity, causing risk, or we must have a very heavy mass, which increases the useless work to be done by the engine. And this has to be, because the piston speed is limited to a moderate velocity, and consequently to get any high ratio of expansion Cornish engines have in many cases to put in motion a much greater weight than that necessary for lifting the column of water in the pumps. To overcome such a difficulty as this the compound engine comes in, because whilst a Cornish engine, with a ratio of expansion 10 to 1, would throw a varying strain upon the engine exactly to

that extent, the varying strain in a compound engine with the same ratio of expansion would not exceed $2\frac{1}{2}$ to 1, the result being a more uniform strain, a lower maximum, and a higher minimum, a more uniform speed, also a lower maximum and a higher minimum, and double the amount of work, because the engine is double-acting. Also the engine has no steam hammer action, and requires no massive and costly foundation, and, being horizontal, can be placed under a pit stage so as to afford no inconvenience whatever to work proceeding. The Cornish engine shows excellent results as regards economy of fuel, although probably this has been over-estimated, but does not stand well when we consider the size of the engine and the first cost. The compound engine holds its own in economy of fuel, and does considerably more work with a less size of engine, because it is double-acting, and can safely work at a much higher average speed, and expansion is available to the utmost limit at which expansion is efficient.

The most beautiful feature, however, of the compound pumping engine is the differential valve-gear, which has been described and illustrated with some care. It has very largely been applied in England and on the Continent, not only to the engine we have described, but to pumping engines of other kinds, and has never failed, because the principle is absolutely correct. To have introduced an arrangement of valve-gear which not only effects substantial economy in the engine of which it is an essential feature, but is also adaptable with good effect to other engines, reflects more than ordinary credit upon Mr. Henry Davey, the inventor. In Cornish engines a misstroke or lessening in the resistance is a serious matter, and to avoid the plunger coming down on the pump bottom, and the pistons going up against the cylinder cover, we have the rude arrangement known as banging pieces, which simply reduce the injurious effect. But the differential valve-gear effectively and immediately adapts the distribution of steam to the increasing and decreasing resistance, and, consequently, results in economy and the avoidance of mishap.

It ought to be mentioned in drawing this chapter to a conclusion, that in at least one important case—namely,

at a large colliery in South Wales, the differential compound engine has been placed underground, and by dispensing altogether with pump rods, is doing excellent work in raising water 1,100 ft. in one lift. And at Staveley one of these engines, with high pressure cylinder 45 inches, and low pressure cylinder 72 inches, and stroke 10 feet, has been at work for several years, and has given great satisfaction. Staveley Collieries have at work pumping engines of many kinds, including Cornish engines and large rotary engines, and the authorities there have unhesitatingly pronounced the compound differential engine superior to all the rest, on the score of economy and efficiency. The experience is that it prevents the violent shocks that almost always take place when engines are working expansively. This particular engine pumps 1,200 gallons per minute under a pressure of 320 pounds per square inch, representing a vertical column of about 720 feet, and so easily and uniformly does the engine do its work that the action of the valves is practically noiseless. An experiment was made at this same colliery by taking the old-fashioned tappit motion from a Cornish engine, and replacing it with the differential motion, and not only was economy effected, but the engine worked much steadier, and the wear of the clacks and the work in the shaft has been much diminished. Also in Germany, the differential valve-gear has been largely applied to Cornish engines, and always with success, the engines being enabled to work at a higher speed with greater safety than before, and the result in more than one case has been that mines on the point of being drowned have been kept right for work.

Pumping engines stationed underground will occupy our next chapter, but it speaks well for the compound differential that it stands foremost amongst pumping engines placed upon the surface, and does good work when placed below, and its gear applicable to other engines. The important position it now occupies amongst mine pumping engines is well illustrated by one recent incident. At the examination in mining held in 1883 all over the United Kingdom by the Science and Art Department, the candidates were required to describe the Compound

Differential Pumping Engine.* The writer hopes that in this chapter he has made the principles, and construction, and capabilities clear of such an eminently successful modern type of pumping engine.

* These mining examinations are referred to elsewhere and have long been matter for anxiety. They have certainly not always comprised questions which could be taken as a fair test of the knowledge possessed by a student of, or worker in, mining, and in this year, 1884, the unfairness seems to have reached a climax which will probably produce a speedy remedy. We want a special examination in coal mining and its appliances, and whilst by no means excluding theory, success at such examinations should be impossible without practical knowledge and experience.

CHAPTER XIV.

PUMPING ENGINES AND APPLIANCES.—PUMPING ENGINES PLACED UNDERGROUND.

Advantages of Surface Pumping Engines—Running Lifts whilst Sinking—Winding Water—Steam Pumps; their Advantages—Most Favourable Conditions under which such Engines can be applied—Causes of weakness in Pipes—How to avoid them—Vertical and Horizontal Casting—American plan of Cooling Castings—Horizontal Fly Wheel Pumping Engines working in Pairs—Conveyance of Steam from Surface—Loss of Pressure—Different Systems of Transmitting Power to Underground Pumping Engines—Steam Engines and Steam Boilers Below—Steam Engines Below and Steam Boilers Above—Air Compressing Engines Above and Pumping Engines Below—Hydraulic Power—Ropes or Chains and Pulleys—Securing Pipes in Shaft—Allowance for Expansion in Steam Pipes—Defective Expansion Joint—Effective Expansion Joints—Dealing with Exhaust from Pumping Engines—Pipe Condenser—Holman's Condenser—Experiments at Norley Collieries—Experiments at Lamb and Moore's Collieries—Hayward Tyler's Condenser—The Blow-through Valve—Speed and Efficiency of Underground Pumping Engines—Examples and Rules as to Power of Underground Pumping Engines.

So far in these chapters on pumping we have dealt with appliances in which the engine is placed on the surface and the pump underground, the connection between them being made by massive pump rods of timber, and plated at the joints. In the early days of pumping at mines this method was universal, and even now, especially when mines are heavily watered, is generally adopted. The advantages of such a system are that the steam supply is close to the engine, and consequently there is little loss under this head, the engines themselves are under better supervision and more easily repaired, and even should the rush of water at any time be so great that the mine is flooded and the water rises above the pumps, the engine

is not drowned, but can go on working until the water is lowered to its proper level. The writer had a case in which a pump arrangement of this kind was stopped for a year; the mine had ceased to work and it was desired if possible to avoid the somewhat heavy expense of pumping, and the water rose during that time very much higher than the pumps. After the lapse of such a long period the water was suspected of making its way to other mines which were in constant work and lay deeper, and the pumps were re-started without any difficulty, and in course of time cleared the mine, and have gone on ever since as if they never had been stopped.

Also in sinking if water to any large extent is met with it is found more convenient to deal with it by what we have termed in previous chapters a running lift, which having its engine on the surface follows the shaft down. This is far better than winding the water; indeed the quantity may be so large that if dealt with by winding the winding engines could do nothing else. We have already said that except in rare cases it is not desirable winding engines should be used for raising water. Under such circumstances a surface pumping engine is inevitable at the first, and it is not often that it is thought desirable to dispense with such an arrangement when the pit has been sunk. But there are other cases where perhaps not much water is found in sinking, or such as can be wound without interference with winding coal or doing work in the shaft, or possibly kept back, or perhaps the quantity much increases as the workings extend, and water in quantity not at first anticipated has to be dealt with. In such cases the pit may be put down without any pump in the shaft, and when this is finished comes the question, Where shall the pump be placed? And in the majority of cases the steam pump settles the question. Of course all pumps driven by steam might be called steam pumps whether the engines be above ground or below, but by the term steam pump is meant specially the arrangement in which the engine and the pump are one, and the piston of the steam cylinder, and the piston or plunger of the pump cylinder are generally on one rod. The advantages of such an arrangement, provided steam can be supplied as economically as in the surface engine, are

evident. We have no pump rods, and few will be bold enough to question the advantage of being able to dispense with long and heavy pump rods, which however well balanced must in any case represent so much dead weight to move about, and which at times give rise to serious mishap, and in any case require a good deal of care and attention, and even the first expense of these pump-rods amounts to something considerable. Then these arrangements are for the most part single-acting, and only pump whilst moving in one direction, because even in the excellent arrangement by Davey of having two pump quadrants with a pump to each, ensuring work both ways, we may require a separate set of pipes and certainly require a separate set of pump-rods to each. The height of the lift, too, is limited, on account of these cumbersome ranges of rods, which become more and more likely to cause accident as their length increases. Also the speed of the arrangement cannot be high on account of the enormous mass of matter that has to change its direction of motion twice in each stroke, necessitating for effective working a substantial pause on each occasion. The steam pumps placed underground avoid these difficulties. A much smaller engine will do the work, because they can always be double-acting, can always work at a higher speed, and dispense altogether with pump rods, and by bringing the engine and pump rigidly into one acting directly upon the water to be raised, avoid the necessity for the pauses referred to.

We have been referring to the steam pump under its most favourable condition—namely, when the steam required is generated close by, that is, having the boiler in the mine close to the pump. The writer had such an arrangement for raising water 1,200 ft. vertical, and a small pumping engine dealt with a quantity of water that would have put a large surface engine to shame, and the consumption of fuel was trifling. (See fig. 94.) The exact quantity of fuel was not arrived at, because the steam boiler also generated steam for haulage purposes, and was utilised to some extent to aid the furnace for ventilation. The reservoir comprised the two sump holes, namely, of the upcast and downcast, and a tunnel some 40 yards long connecting them, the water flowed into or





was brought to this reservoir from various parts of the mine. (See figs. 95 and 96.)

An interesting incident in connection with this arrangement is worth mentioning. The pipes were not large in diameter, being only 4 in., but the pressure being great, strength was considered an essential, and the pipes were made, as was thought, thick enough, and each one tested to even more than the maximum pressure. Although this was done several pipes gave way shortly after being set to work, and on examination were found in cross section not as shown in fig. 97, concentric the outer with the inner diameter, but as in fig. 98, beautifully eccentric. Several lessons were drawn from this incident, first, that thickness in a pipe is not necessarily strength, and second, that all pipes should be cast vertically. If cast horizonally the eccentricity just referred to is to some extent inevitable.

We have previously laid down some rules as to strength of pipes, and a table of strengths for certain diameters and certain thicknesses. We have pointed out that a certain amount of metal over and above the theoretic requirement for strength is needed, to allow for wear and tear and knocking about and sudden shocks. But it may be said here that unless great care is exercised in the casting and cooling, thickness becomes weakness instead of strength. Pipes to resist pressure should be made of metal which will allow a safe working load of not less than 2,800 lb. per square inch tensile strain, should be cast vertically to ensure uniform thickness, and a system introduced in America some time ago of cooling them from the inside is worth consideration. By this means each outer layer fits itself tightly on the inner layer and forms a structure under uniform strain, whereas by cooling from the outside each inner layer has so little in common with the outer layer in immediate contact that the casting becomes more a combination of loose concentric rings than anything else, and the pipe is not under uniform strain.

The pumping engine referred to was horizontal, with circular motion, having two fly-wheels, and the writer may remark here at once that although pumping engines without such motion will also in this chapter be

described, in his opinion the most effective steam pump arrangement underground is a pair of horizontal double-acting pumps with cranks and fly-wheels, and made so as to work either together or separately—that is, either engine separately equal to the column, and by having the height of suction pipes—that is, the vertical height from water to pump—as short as possible. Of course, by having a considerable area of storage for water this can be effected conveniently enough; and if for such an arrangement we can have steam boilers close to, and a condensing arrangement, there is no other pumping appliance equal to it.

But if we go to the other extreme and have pumping engines at the bottom of a shaft of considerable depth, or away distant from the shaft in the workings, and steam has to be brought from the surface, then the results do not come out nearly so well, because the steam loses power on its way. Of course, so far as the shaft itself is concerned, much depends on whether it is upcast or downcast. If a furnace shaft, the steam will lose nothing on the way, may even gain something, but there is the inconvenience of making joints or renewing a pipe in a furnace shaft, because the ventilation of the mine has practically to be suspended, and the injurious influence from furnace gases counterbalances any advantage from heating influence. Pipes of a considerable thickness will under the noxious influence of these furnace gases be in a few years absolutely eaten away. The writer found that at the bottom of a shaft 400 yards deep the difference in pressure was nearly 10 lb., and in another case, with a shaft 200 yards, and 600 yards additional in the workings there was a difference of nearly 20 lb., although the pipes were covered, which may be taken as not far from the actual loss experienced. This may seem a large reduction of pressure, but steam which has to travel half-a-mile, and mostly through a cold current, will necessarily be seriously affected.

Then again, if we take a case where steam cannot be taken into the pit at all, and compressed air has to be used, all comparisons will be against the pumping engine in the mine, not through fault of the engine itself, but because compressed air gives a remarkably low useful

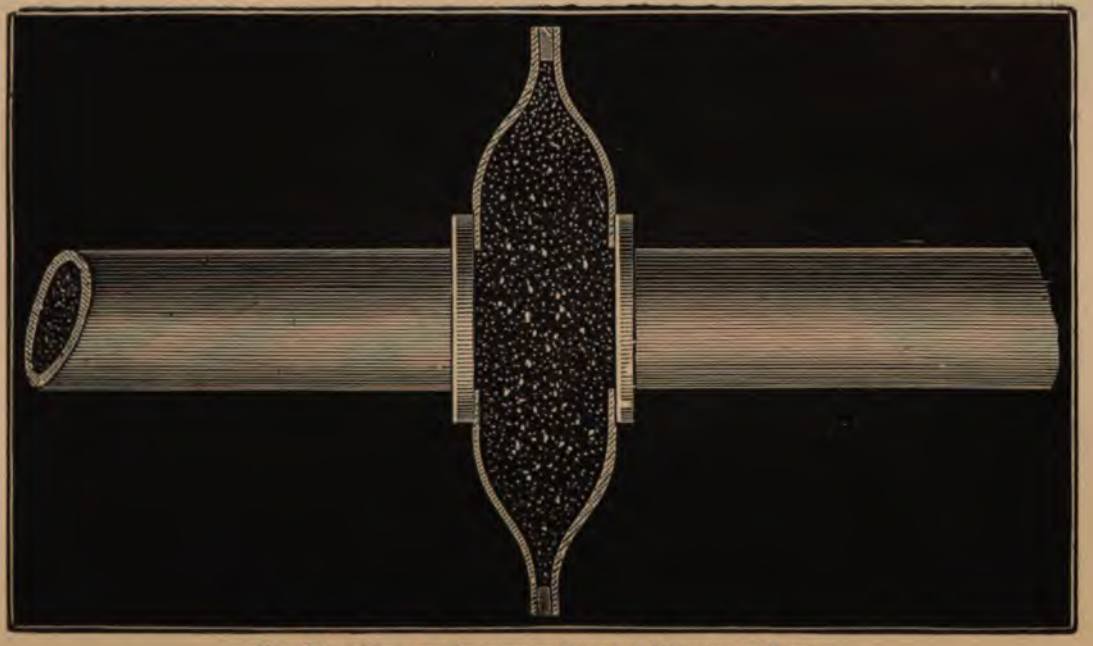


FIG. 99.—OLD AND DEFECTIVE FORM OF EXPANSION JOINT.

[*To face page* 145.]

effect, about which we shall have more to say in the section on haulage.

There are three ways, therefore, in which we may apply pumping engines underground, namely, first, with steam boilers close to the engines, in which case we get results with which no other system can compare; second, with steam conveyed from the surface, in which case, however well we cover the pipes, there will, in an ordinary downcast shaft, be a loss of a pound or two of steam for each 100 yards in length of the pipes; third, we may use compressed air, which, while absolutely safe and producing no trouble worth mentioning with ordinary care, will from an economical point of view compare unfavourably with any other arrangement. There are one or two other smaller methods of pumping, such as hydraulic power, and by means of a rope and clip pulley. These systems may be referred to, but the three methods just named are by far the principal ones.

With steam underground we have only the delivery pipes in the shaft, and these simply require to be fixed firmly and vertically, and no provision has to be made for expansion, and pipes have not to be covered; but if there are any corners or bends at which air can lodge, we should provide for its escape. With steam conveyed from the surface we have a column of pipes down for steam and a column of pipes up for water, and the former should have provision made for expansion, which may simply be taken at a maximum capability of 6 in. per 100 yards. In former days a very common expansion pipe was as shown in fig. 99, which is very defective, because whilst making provision for lengthening the pipes, if additional length were required, it not only did not provide for pipes running into each other, but actually resisted this with an enormous force. This is easily perceived from the fig. 100. Suppose such an expansion joint on a pipe 6 in. diameter, and suppose the largest diameter of the discs on which pressure can act to be 18 in. This represents an annular surface of 18 in. outside and 6 in. inside, being equal to an area of 226 square inches. If the pipes are cooling, their contraction is assisted by the steam pressure, whatever it is, upon an area of 226 square inches. But if the pipes are getting hotter, their

expansion is opposed by pressure acting upon this area. So that these so-called expansion joints facilitate contraction and oppose expansion. Even if such appliances allowed expansion and contraction with equal freedom, the bending and buckling of the plates which this would cause would prove an element of danger. And, as a fact, several accidents some years ago, almost amounting to the dignity of boiler explosions, sounded the death knell of these mis-called expansion joints. Figs. 100, 101, 102 show what may be considered a fair expansion joint arrangement, and a good plan is to place one allowing for a movement of 12 in. each 200 yards. It must be remembered that these expansion arrangements need attention; if not, one of two evils arise, either they become fast and useless, or else they leak and are wasteful. A little care will avoid either of these. In the expansion arrangement shown, we have supposed the piston portion fixed by brackets upon the horse-tree, and the cylinder portion is free to rise under the influence of expansion. The column of pipes between each expansion must be free to rise or fall between the horse-trees and pudlocks. Figs. 103 and 104 show the securing of the water pipes in the shaft. In this case there is no expansion to provide for, and the pipes are not only maintained vertically, but are secured firmly to the horse-trees and pudlocks between which they pass.

An important matter with regard to underground pumping engines is dealing with the exhaust. We want the effective power obtainable by condensing arrangements without the usual elaborate condensing appliances, and we want the exhaust so thoroughly dealt with that no inconvenience is caused in the mine. Unless the pump is placed quite close to the pit bottom, to allow exhaust steam is practically impossible, because it cannot be allowed to go roaming freely about the mine, heating an already overheated atmosphere and pulling in the roof, and a long range of exhaust pipes is not allowable, because it causes an enormous back pressure; and even when the pump is at the bottom the exhaust is something more than a nuisance.

Fortunately, appliances of a very simple character have been found effective for these pumping engines; they



URING COLUMN OF
T.

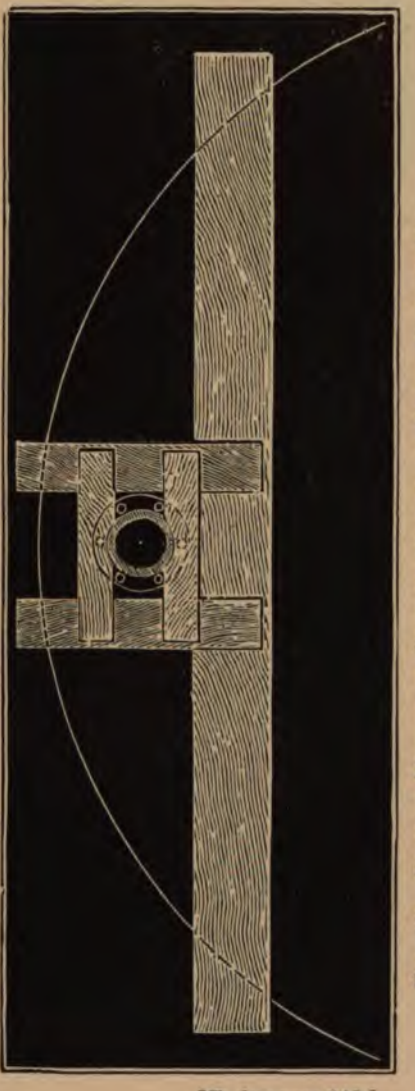
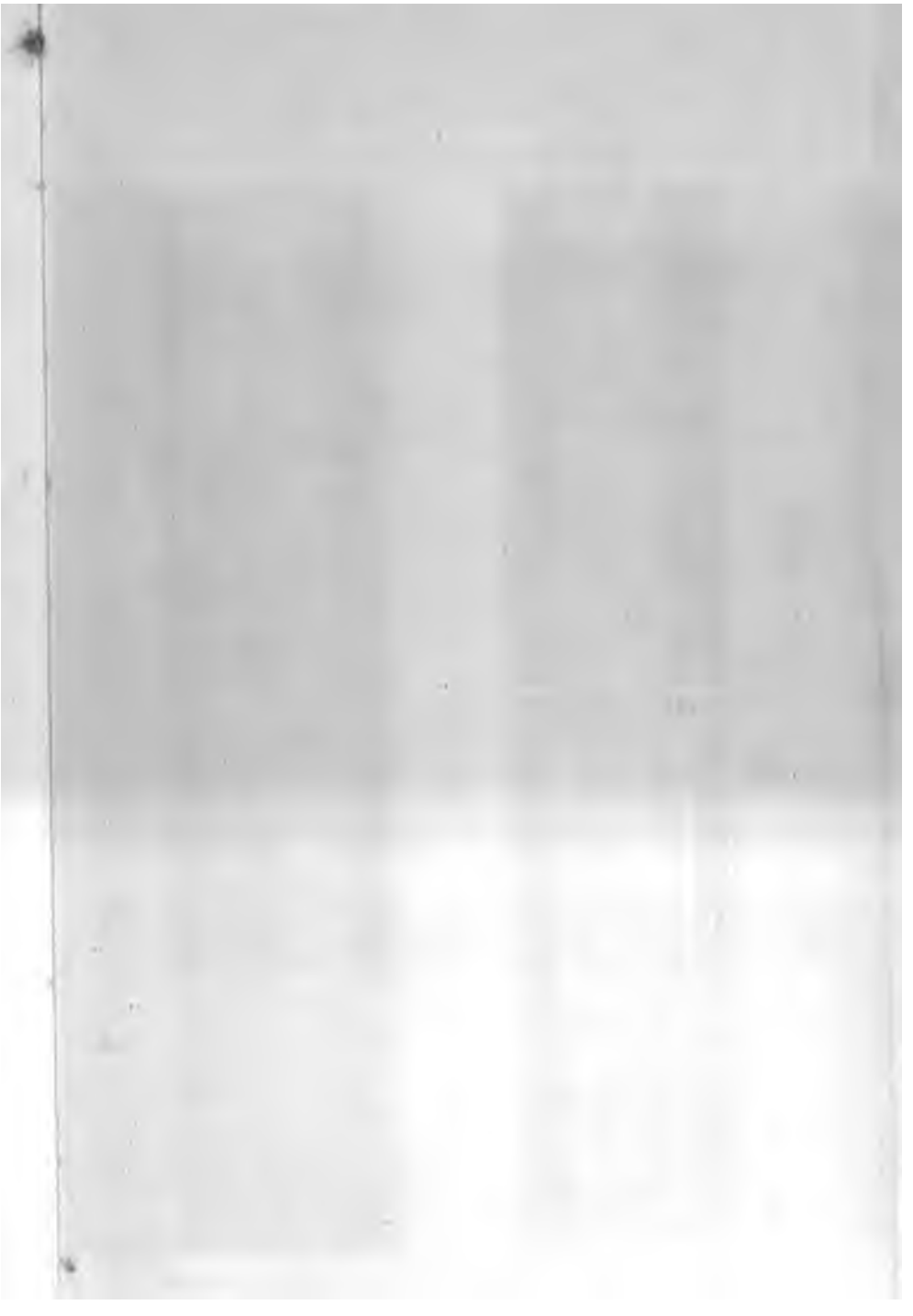
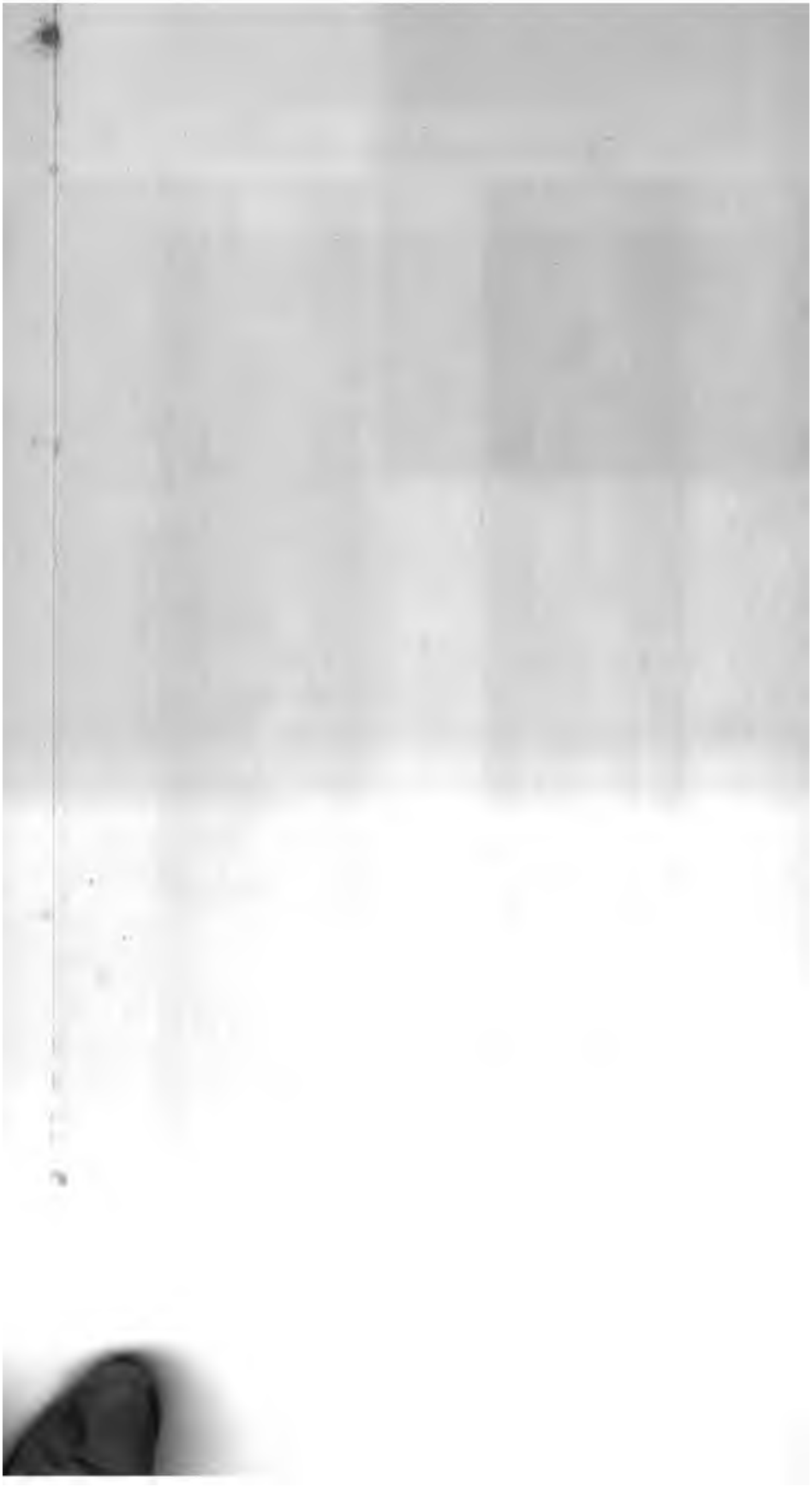


FIG. 104.—PLAN OF METHOD OF SECURING COLUMN OF WATER PIPES IN PIT.

[*To face page* 146.]






N

take up scarcely any room, have practically no working parts and do their work well. Fig. 105 shows a condenser in its simplest form. A stream of cold water passes down the pipe A, while one or more branches admit exhaust steam from an engine through the pipe B. The effect of this arrangement is a more or less perfect condensation of steam; and if the current through A is sufficiently powerful a very fair vacuum may be sustained. It is especially suited for small pumping engines when A becomes the suction and B the exhaust pipe. The writer obtained very fair results with an arrangement of this simple kind, but unfortunately the pump clacks at first were of leather, which was injured by the suction water sometimes getting very warm. Afterwards this defect was remedied. The pit shaft was provided with a pumping arrangement worked from the surface, and this dealt with all water made in the shaft. But as the dip workings extended some 700 or 800 yards at an inclination of 1 in 6, and as considerable water was found there, special means were necessary to deliver this water into the sump, to enable the shaft pump to raise it to the surface; and at such a distance in the mine exhaust steam was not desirable, and so long a range of exhaust pipes to convey the exhaust to the pit shaft was impracticable. The simple contrivance shown in fig. 105 did not perceptibly increase the power of the engine, nor lessen its delivery of water. But it did dispose of the exhaust. Fig. 106 shows a more elaborate arrangement on the same principle, which has been largely applied, and has been very successful. The suction pipe of a pump receives water and exhaust steam through two conical valves, and so condensation takes place, thus disposing of the exhaust steam, and a fair amount of vacuum is produced. This condenser of Holman's, as applied to the well-known steam pumps of Tangyes, is shown in figs. 108 and 109, and has been very extensively applied, and obtained very considerable success. At the Norley Collieries some experiments were made with one of these condensers attached to a steam pump with steam cylinder 8 in. diameter and pump 4 in. diameter, forcing water 40 ft. vertical, and raising the suction water 5 ft. The steam pressure was a little over 30 lb., the exact pressure at 80 yards from the pump being 36 lb. When working

without the condenser the speed attained was 88 piston feet per minute, and when working with the condenser the speed rose to 168 piston feet per minute, the quantity of water per foot of piston remaining the same. This increased speed was owing to an obtained vacuum of 10½ lb., and as working non-condensing, the back pressure would not be less than 5 lb., leaving an effective pressure certainly not exceeding 25 lb., we add in this case 15 lb., being equal to 60 per cent., by the application of the condenser. This increased power accounts easily enough for so material an increased speed in the pump.

At Lamb and Moore's collieries also—and the writer mentions these cases specially because they are near his own home and came under his special notice at the time—Mr. Scarborough made some very interesting experiments. There were two pumping engines with 30 in. cylinders, 10 in. pumps, and 4 ft. stroke, raising 40,000 gallons per hour to a vertical height of 500 ft., and working 100 piston feet per minute. Working without the condenser and with a steam pressure of 36 lb., the speed was 22 strokes per minute, with a steam pressure of 31½ lb., the speed was 18 strokes per minute. Working with the condenser a speed of 22 strokes per minute was obtained with 25 lb. steam pressure, and a speed of 18 strokes per minute attained with 21 lb. steam pressure, the quantity of water per stroke being in all cases the same. So that in these experiments we have shown a reduction of steam pressure of 10½ lb. in the one case and 11 lb. in the other. This is effected by the removal of the back pressure and the obtaining some vacuum, and although the vacuum thus obtained does not come out so high as at Norley, it probably gives a much more reliable proof of what these condensers are capable of doing where both the lift and the quantity of water are considerable. These experiments date as far back as 1874, when the promoters of these special steam pumps were making vigorous endeavours to have them introduced in all the great mining centres, but the pumps here mentioned have been working ever since. Mr. Scarborough in a letter kindly addressed to the writer while this chapter was in preparation for the press, says that the condensers continue to give satisfaction and the pumping engines

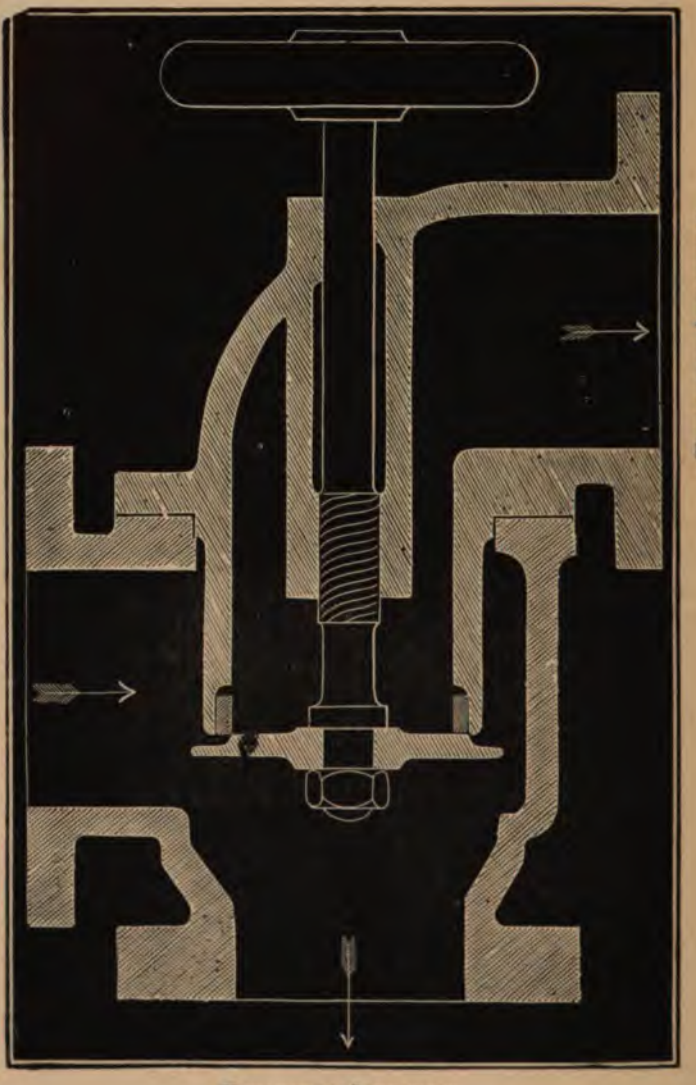


Fig. 110.—Blow-through Valve used where Condensers are attached to Steam Pumps.

[*To face page* 149.]

do their work fairly well. This, after nine years' continuous work is very gratifying, and although the writer is by no means enamoured of this type of pump, no treatise on pumping appliances would be complete or even fair that did not place such information before the reader. The Holman condenser, as shown in section in fig. 106, is very simple in construction. It consists of a valve box having one or more valves (or deflectors) with single beats, and seats in which are formed annular steam spaces, through which the exhaust steam (at whatever pressure it leaves the cylinder) issues in thin annular streams to meet the water passing over the valve seats. The idea is to operate upon a large surface of the exhaust by the cold water, and thus make condensation precipitate. Figs. 108 and 109 show Holman's condenser in elevation and plan attached to a pump. The condenser forms part of the suction pipe, and it is claimed for this appliance that whilst it effectually condenses the exhaust steam, it produces an average vacuum of about 10 pounds per square inch on the steam piston, and effects a saving of from 20 to 50 per cent. in fuel, and increases to a corresponding extent the efficiency of the engine, and is suitable for any kind of steam pump. Probably the actual results are not so great as here stated, but the reason for adopting these condensers at all in mining operations was that they got rid of the exhaust steam, and this is so important for underground workings that, if they effected no economy at all, still their value would be very great. Steam, so far, is the least expensive motive power we have, and these condensers enable us to use steam where otherwise it would be impossible. Fig. 107 shows another condenser by Hayward, Tyler and Co., of a somewhat similar kind. When these condensers are attached to pumps it is necessary to have some arrangement whereby the pump can be started without the condenser, and in case of need worked without it.

Fig. 110 shows the arrangement known as the blow-through valve, which is placed in the conducting pipe for conveying exhaust steam from the cylinder to the condenser, and takes the place of two ordinary stop valves. The disc valve at the bottom of the spindle is faced on both sides, and when screwed up closes the out-

let to the atmosphere, thus carrying the steam in the direction of the lower arrow towards the condenser. When the pump is first started, it is necessary to exhaust into the atmosphere in order that the pump, cylinder, and pipes may be fully charged with water before the steam is let in; and this is effected by screwing down the disc, thus closing the way to the condenser, and opening a passage to the atmosphere in the direction of the upper arrow.

As to the speed at which these underground pumping engines will work, that will depend somewhat on the length of the stroke, the number of revolutions diminishing, but the actual speed of the piston increasing as the stroke is greater. There is no difficulty in working a small pumping engine with a stroke of 12 in. at eighty strokes per minute, making 160 piston feet, and with larger engines having a stroke of, say, 5 ft., we can well enough make thirty revolutions, making piston speed 300 ft. per minute. This refers to engines with crank and fly-wheel motion; engines of the special type cannot be worked so quickly. It goes without saying that pumping engines are better with long strokes. There is always some loss at the return, and the greater the number of revolutions the greater this loss will be. They are more economical, because making fewer strokes for the same piston speed, they have to fill the clearances between the piston and cover a fewer number of times. And suppose a pump having a stroke of five inches misses one inch each stroke as regards actual work (because no pump ever discharges its theoretic capacity), that represents 20 per cent. loss, whilst with a stroke of 5 feet it would hardly be 2 per cent. The engine having to change its motion less often, there is less strain upon the engine in all its parts, and the valves, by not having to open and close so frequently, have less wear and tear and act more accurately. A good pumping engine should have a delivery within 5 per cent. of the theoretic capacity.

At this point of our article we will take two examples, first, to determine the size of underground pumping engine required to do certain work; and second, to determine the quantity of work a given underground pumping engine is equal to. We want to raise 20,000 gallons per hour from

a depth of 300 yards, and we have an effective steam pressure of 30 lb., and propose to work the engine at 250 feet per minute; and we have to determine the diameter of the pump and of the piston, both of which are double-acting — 20,000 gallons an hour = 333 gallons per minute, and if the pump runs 250 ft. per minute, 333 ÷ 250 = 1⅓ gallons for each foot the pump works. A gallon = 276 cubic inches, and 276 × 1⅓ = 368 cubic inches in each foot of the pump; 368 ÷ 12 = 31 square inches area nearly = 6¼ in. diameter, but allowing 3 in. dia. = 7 square inches area for pump rod, gives us a total area of 38 square inches = 7 in. diameter of pump. The column of water is 300 yards = 900 ft., representing a pressure of 900 × 15 = 13,500 ÷ 34 = about 400 lb. per square inch × 31 = 12,400 lb. total pressure on the pump. The steam pressure is 30 lb., and 12,400 ÷ 30 = 413 square inches area, and adding one-half to the area theoretically required, as an allowance for friction, &c. = 620 square inches area = 28 in. diameter of cylinder, showing that a pumping engine with 28 in. steam cylinder and 7 in. pump with 30 lb. effective steam pressure would deal with 20,000 gallons an hour from 300 yards. Having determined the diameter of pump and piston, we can make the length of stroke at pleasure, always remembering the advantages of long strokes. In this case, with cylinder 28 in. diameter, 5 ft. would appear a convenient stroke, because, other conditions being the same, a steam engine has good proportions when the stroke is about twice the diameter. Such a pump would work, according to the terms of our example, 25 revolutions per minute.

Now, the second example; we have a pumping engine whose stroke is 3 ft., the steam cylinder 30 in. diameter and the pump 10 in. diameter, and can rely upon a steam pressure of 35 lb. per square inch upon the piston; what quantity of water can we raise and from what depth? This engine could work well enough at forty revolutions per minute = 240 feet. The pump, 10 in. diameter, will probably have a rod 4 in. diameter = 12½ square inches area, reducing the effective area of 10 in. diameter from 78½ to 66½. The cylinder, 30 in. diameter, will have an area of 706 square inches, and deducting one-third for friction, &c., leaves us 706 — 235 = 471 square inches

area, on which a pressure of 35 lb. operates; therefore 471 × 35 = 16,485 available effective useful power. The effective area of pump is 66½, and 16,485 ÷ 66½ = 246½ lb. pressure which the pump can support; 246½ × 34 = 8,381 ÷ 15 = 559 ft. high of a column. And to find quantity, 66½ × 12 = 798 cubic inches in each foot ÷ 276 = 2·9 gallons per foot, × 240 = 696 gallons per minute, × 60 = 41,760 gallons per hour—showing that this pumping engine, having steam cylinder 30 in. diameter, pump 10 in. diameter, stroke 3 ft., running forty revolutions per minute, and having effective steam pressure 35 lb. upon the piston, will deal with over 40,000 gallons per hour from depth of 559 ft. It may be well for some of our readers to put into the form of simple practical rules the methods of working out such examples.

First. Having given the quantity of water, and the depth, and the effective steam pressure of steam upon the piston, and the intended piston speed, to determine the diameter of the pump and of the steam cylinder. Find the number of gallons that will have to be dealt with for each foot that the pump works, bring these gallons into cubic inches by multiplying by 276; then to find the area of the pump divide these cubic inches by 12. An allowance will have to be made for the pump rod, according as it works on one or on both sides. The size of rod is arrived at as follows:—The pump rod will equal the piston rod, which for pumping engines having a tolerably uniform amount of strain may be taken at one eighth the diameter of the piston. Having found the area of the pump, we find the pressure of the column by multiplying the height in feet by 15 and dividing by 34. This pressure multiplied again by the area of the pump in square inches gives the total pressure in pounds upon the pump, to which we add one half the total for frictional resistances. Having found the work we must determine the power. The work divided by the effective steam pressure gives the area of the steam cylinder, and it will hardly be necessary to allow for the piston rod, because the area of rod is small compared with area of piston and the allowance made for frictional resistance is a sufficiently large one. Having the areas we find the diameter

in the usual way by dividing by 0·7854 and finding the square root of the product.

Second.—Having a pumping engine of given dimensions, and knowing the effective steam pressure upon the piston, and the intended piston speed, to determine the quantity of water and the vertical lift. Deducting from the pump diameter the diameter of the rod we find the effective pump area. We then find the area of the steam cylinder and deduct one-third for frictional resistances. We multiply the remainder by the effective pressure of steam and this represents the power. Divide this power by the effective area of the pump, and we have the pressure in pounds per square inch against the pump, which multiplied by 34 and divided by 15 gives the vertical lift. Then to find quantity we multiply the effective area of the pump by 12, which gives us the cubic inches in each foot, and divided by 276 gives the number of gallons which each foot travel of the pump raises. This multiplied by the speed of the pump in piston feet per minute gives the quantity of water in gallons per minute.

By effective pressure of steam in these two rules we mean the actual pressure upon the piston from which indicated horse power is calculated. We make also in the rules no allowance for area of piston rod. In the first example with cylinder 30 inches the area of rod would only be about one-sixtieth the area of the piston.

In these two examples it has been assumed that the average underground pumping engine with crank and flywheel motion will work at a piston speed of from 200 ft. to 250 ft. per minute, and that of the full power of such an engine one-third should be considered as allowed for frictional resistances, &c. This margin may seem large, but the steam pressure may fall at times, and a pumping engine, like a winding engine, should be more than equal to its work, so as to do it easily. An engine, of course, may be too large, and if so is wasteful, which is unfortunate; but if an engine is too small it becomes for pumping simply useless.

CHAPTER XV.

PUMPING ENGINES AND APPLIANCES.—PUMPING ENGINES PLACED UNDERGROUND.

Messrs. Joseph Evans and Sons, of Wolverhampton—The Cornish Steam Pump—Its special Advantages—The Patent Rotating Disc Valve—Importance of good Valve Arrangements in Pumps—Quick Opening and Closing without undue Concussion—Sufficiency of Opening—Suction Air Vessels—The Cornish Double Ram Steam Pumping Engine for moderate or high Lifts—Plungers most effective for great Pressures or for dirty Water—Valves with India-rubbers or Springs at the Back to ensure quick Closing—The Cornish Direct-acting Steam Pump for moderate Lifts—Pump Piston or Bucket—Cornish Pumps popular on account of Cheapness and Simplicity and small Space required—They are not Economical—The Horizontal Double-acting Ram Pumping Engine with Fly-wheel—Its Advantages—The Vertical Fly-wheel Ram Steam Pump—The Horizontal Cornish Compound Condensing Pumping Engine—Specification of Pump to raise 20,000 gallons an hour 450 feet high with 35 pounds of Steam—Hydraulic Pumping Engine for Mines—Circumstances under which Hydraulic Power is effective—Underground Pumping Engine worked by Endless Rope and Clip Pulley—Pumps at Hargreaves' Collieries, Burnley, worked by Endless Chain—Testimonial to Messrs. Joseph Evans and Sons from Amsterdam.

In no branch of engineering have English manufacturers displayed more ingenuity and excellence than in pumping machinery. There has been a difficulty in making selections amongst so much that is good, and the examples here presented are those with which the writer has had some practical experience, and the materials for description and illustration were ready to hand. Figs. 111 to 124 are all representations of pumping engines taken from actual practice. They represent the leading specialities

suitable for mining operations of the long-established and eminent firm of Messrs. Joseph Evans and Sons, hydraulic engineers, of Wolverhampton, whose long-continued and ever-increasing excellence in all kinds of engines and machines for pumping has made them famous at home and abroad. The writer has given careful attention to their machinery, and has had the good fortune to have considerable experience with it, enabling him to speak with confidence.

Fig. 111 gives a sectional elevation and fig. 112 a sectional plan of what is known as the Cornish steam pump. It is a horizontal arrangement, and has no circular motion, and occupies exceedingly little space. The letters of reference upon the figs. 111 and 112 are as follow:— A, steam pipe; B, exhaust pipe; C, steam cylinder; D, steam chest; E, starting lever; F, distance piece; G, air vessel; H, delivery branch; K, pump; L, suction; M, delivery valve (patent rotating disc valve); N, suction air vessel; O, suction valve; P, bucket; R, doors for access to valves. Its general advantages may be briefly described. It, unlike many pumps of this class, has no tappets, and consequently no metallic impact in the mechanism of the valve, the steam plungers being properly cushioned and quite noiseless in action. This absence of tappets also ensures simplicity and consequent durability in wear. In this Cornish steam pump there is an arrangement of shooting or puff holes to produce the necessary action which at the same time effect the most positive motion that direct-acting pumps are capable of. Another great advantage of this valve arrangement is that it ensures perfect control over the steam piston, and accordingly the pump will start at any point of the stroke, and will work at any speed, high or low, with a certain and continuous action. The steam ports are so arranged that the steam cylinder is effectually drained at all times when the pump is at work, and therefore no drain cocks are required as in most other direct-acting steam pumps, and water does not lodge in the steam cylinder, causing certain loss and probable mishap. The steam pistons are packed with broad metallic rings. The pump end of the engine is provided with top and side doors for access to the valves, these being of novel type and arranged as shown in figs. 113 and 114.

The grid seats are of gun metal, and the valves themselves are of rubber. Rotative motion is produced in the valves by means of the angle at which the water passes through the seat, the holes in the latter being diagonally set around the centre. As ordinarily arranged, the action of water passing through valve seatings tends only to open the valves, but in this case a circumferential movement is given to the valves, compelling them ever to change their position. An objection to the india-rubber valve has been the great amount of wear caused by the rubber constantly beating in one position over the same hole or holes. This is entirely obviated by the rotative motion introduced, which renders the valve one of the least expensive in use. The grid never requires renewal, and when new valves are needed they can be provided at nominal cost and replaced in a few minutes, and this expeditious and economical renewal is a very important matter in connection with pumping engines in mines.

Fig. 113 shows the arrangement in plan, one-half giving the view of the guard which regulates the rise of the valve, and the other half shows the grid seat with guard and valve removed. Fig. 114 gives a section of the seat, the valve, and the guard. The valves in all pump arrangements are an important element in the working, and will make nearly all the difference between efficient and non-efficient work. Valves should open quickly to the full extent of their opening, and should close quickly with as little concussion as may be. Delay or insufficiency of opening puts useless work upon the engine and needless strain upon the parts. Delay in closing lessens the useful effect, and excessive concussion soon destroys the tightness of the valve. The rotating disc valve shown in figs. 113 and 114, as applied to pumping engines working against low and even moderate lifts, has given great satisfaction even in quick-working short-stroke engines where the valves are scarcely ever at rest. Suction air vessels have been proved useful adjuncts to low-lift pumping engines, and are always provided on the pump illustrated. Fig. 115 shows a horizontal Cornish double-ram steam pumping engine which answers well either for moderate lifts or for high lifts. The steam end of the pump is exactly the same as in figs. 111 and 112,

but the pump end is entirely different, having double rams instead of the ordinary double-acting piston end. The various parts are indexed as follows:—A, steam cylinder; B, pump barrels; C, ram; D, valve boxes; E, suction valve; F, delivery valve (conical gun metal valves with india-rubber buffers); G, delivery pipe; H, stuffing boxes; K, suction pipe; L, steam pipe; M, face of exhaust pipe. A different arrangement of valves is shown in fig. 115, this type of pump being recommended for high lifts, and the india-rubber valve comes out best for lifts that can scarcely be called high. This design is a special one for very high lifts, the plunger type being admittedly the best arrangement by far for great pressures or for dirty water, because the piston has to be kept tight all along the length of the cylinder, and the dirt can come in contact with the surface that the piston is constantly travelling over, whereas the plunger only has to be kept tight at one permanent place, and the dirt cannot well get at the surface of the packing on which the plunger rubs. All the pump parts are cylindrical, affording great strength, and the various portions are so arranged that they may be readily renewed without necessitating an entirely new pump. The foundation, or bed plate, is cast in halves, when so required, for convenience of fixing, &c. The valves shown in this figure have at the back india-rubber buffers or springs for ensuring the expeditious closing, and they are found to work well.

Fig. 116 shows an arrangement of Cornish direct-acting steam pump suitable for moderate lifts not exceeding about 200 yards. Here the double-acting piston is again substituted for the plunger and for lifts of 200 yards, when the water is not very clear, or for even higher lifts, when the water is clear, good work is done. The various parts are indexed as follows:—A, steam cylinder; B, distance piece; C, valve boxes; D, delivery pipe; E, suction valve; F, delivery valve (patent rotary india-rubber disc valves, gun metal grids); G, pump barrel; H, door for access to suction valve; K, suction pipe; L, hand holes for threading bolts; M, steam pipe; N, exhaust pipe; P, doors for access to delivery valves. Figs. 117 and 118 show the construction of the piston or bucket used in pumps as per figs. 111, 112, 116. Fig. 117 is the section,

and fig. 118 is the end elevation, and with sufficient clearness give the construction. The leather rings shown round the circumference form a good wearing and tight fitting pump piston. Condensers may be attached to any of these Cornish pumps on somewhat the same principle as those shown in figs. 105, 106, 107 of this article.

All the steam pumps just illustrated and described are of the so-named "Cornish" type, having simply a reciprocating motion. They are very popular on account of their cheapness, and certainly owing to their simplicity. In many cases they are inevitable, because they can be placed in places where the room is not nearly sufficient for pumping engines of other kinds. But whoever the maker may be, this type of engine cannot be considered economical, for the simple reason that no provision is made for expansion. Full pressure of steam has to operate upon the piston all through the stroke, the work to be done being constant; and there are no parts, either a fly-wheel or heavy mechanism of any kind in which work can be stored up at the beginning of the stroke and given out at the end. But they are inexpensive, easy to fix, work well, and can be put in almost any space, however, cramped. Fig. 119 introduces a horizontal double-acting ram pumping engine with fly-wheel, and this is the type of pumping engine which the writer, in this article, has already said excels all others for pumping below ground. It is very true that for engines placed on the surface fly-wheels have, as in the Cornish pumping engine, been dispensed with, and with advantage; and it is quite true also that a fly-wheel of itself entails some resistance upon an engine; but pumping engines on the surface are different—they have attached large masses of pump rods, &c., amounting in most cases to many tons, moving in alternate directions. Sudden changes of motion in such a mass are a disadvantage, and a pause at the end of each stroke is desirable, and fly-wheels make these pauses impossible. But pumping engines underground have no ranges of pump rods, and have only to deal with the column of water which is always travelling in one direction. What we want is to keep up this motion of the column and make it as uniform as possible. This a fly-

wheel, or, what is better, a couple of fly-wheels, accomplish, and enable a high uniform speed to be attained, and avoid the heavy expense of using steam non-expansively. The various parts of this fly-wheel pumping engine are marked as follows:—A, steam cylinder in section; B, piston (part section); C, suction valve; D, delivery valve (conical valves with india-rubber buffers); E, pump barrels (left side in section); F, ram (part section); G, delivery pipe (left side in section); H, valve boxes (left side in section); K, connecting rods; L, fly-wheels; M, plummer blocks; N, crank; O, stuffing boxes; P, suction pipe (both sides of pump bed); Q, piston rod; R, slide valve (in section); S, steam chest (in section); T, eccentric rod; U, eccentric; W, bed (in two parts); X, holding-down bolts; Y, hand hole for threading bolts; Z, crosshead pin. The steam cylinder is of ordinary engine type, fitted with piston and metallic rings and steel piston rod. Pump end with double-acting horizontal rams in line with massive wrought-iron crosshead in centre of ram, and connected to cranks by two strong connecting rods with gun metal steps. Cranks made of best scrap and bent by hydraulic pressure. Fly-wheels securely keyed on the shaft. Valves of improved rotating type, as described for the "Cornish" pumps. Doors for access to each valve provided on the top for delivery valves, and at each end for suction valves. The design of the pump parts exposed to pressure is of the best form, viz., cylindrical, to stand high pressures, and is so arranged that if any breakage occurs to a part or limb it is not necessary to have an entirely new pump end. The whole mounted on massive cast-iron bed provided with hand holes for easy access to bolts, and suction pipe with branches on both sides of same. Whatever the writer of this article may say, the majority of underground pumping engines will continue to be reciprocating machines, having no circular movement; and in many cases probably such an arrangement is inevitable. There are, however, other instances in abundance where space can be provided for such engines as fig. 119 represents. Such an engine would work safely at a higher speed with greater economy, and the length of stroke being determined exactly, there is no waste from a deficient stroke at one time, and danger of cylinder end going out at another time by the stroke

being made too long. False economy at the beginning has as regards pumping engines to be paid for dearly in the end.

Figs. 120 and 121 illustrate a fly-wheel ram steam pump of the vertical type, which is much in favour at and about collieries. It occupies but little ground space, and whilst showing good results, is not likely to get out of order. The parts are lettered as under:—A, steam cylinders; B, rams; C, pump barrels; D, air vessels; E, fly-wheel (in two parts); F, wrought-iron double crank (in one piece); G, kites; H, connecting rods; K, steam pipes; L, exhaust pipes; M, suction valve, and N, delivery valve (patent rotary india-rubber disc valves, with gun metal grids); O, suction pipe (both sides of pump); P, delivery pipe (both sides of pump); R, doors for access to valves; S, eccentrics; T, stuffing boxes; U, valve guard. The figures show a double "ram" steam pump. Two steam cylinders and two rams, with cranks set opposite each other. Column on left is in section, showing arrangement of water passages, valves and air vessel. The suction and delivery pipes can be connected to either side of pump, and there is a door opposite each valve for access to same. In placing such an engine underground a little more height would be requisite, and the foundation would need to be more substantial than with a horizontal engine. Fig. 122 shows a horizontal Cornish compound condensing pumping engine; and enough has been said already in this series of articles on pumping as to the advantages of compounding and condensing to render unnecessary enlarging upon those principles here. Such an arrangement, of course, costs more at first, requires more expensive foundations, occupies considerably greater space, and on that account is not available everywhere. The parts of such an engine are marked as below:—A, high pressure cylinder; B, valve chest for high pressure cylinder; C, low pressure cylinder; D, valve chest for low pressure cylinder; E, valve spindle for high pressure cylinder; F, connecting rods; G and H, rocking levers; J, rocking shaft; K, valve spindle for low pressure cylinder; L, piston rod; M, steam inlet pipe; N, steam pipe from high to low pressure cylinder; O, exhaust pipe; P, condenser; Q and Q′, pump valve boxes; R and R′, pump barrels;

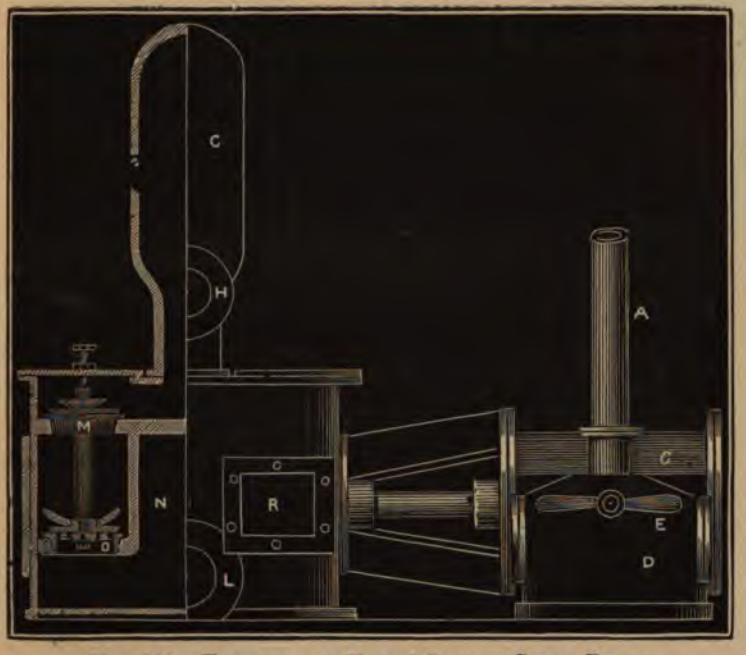


FIG. 111.—ELEVATION OF EVANS' CORNISH STEAM PUMP.



FIG. 112.—SECTIONAL PLAN OF EVANS' CORNISH STEAM PUMP.

[*To face page* 160.]



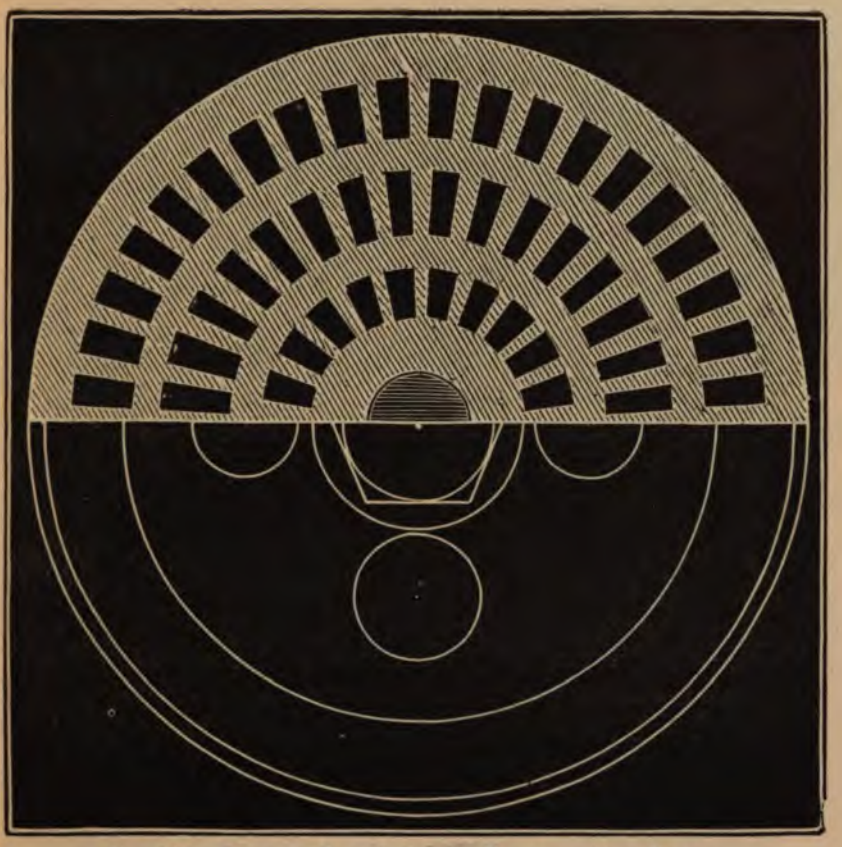


Fig. 113.—Plan of Evans' Patent Rotating Disc Valve.

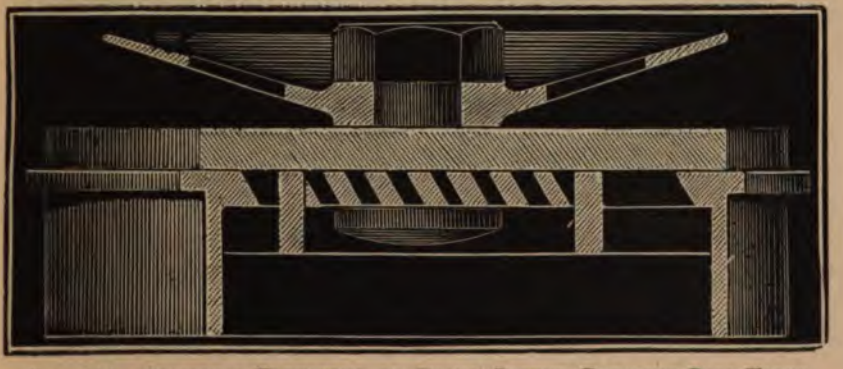


Fig. 114.—Sectional Elevation of Evans' Patent Rotating Disc Valve.



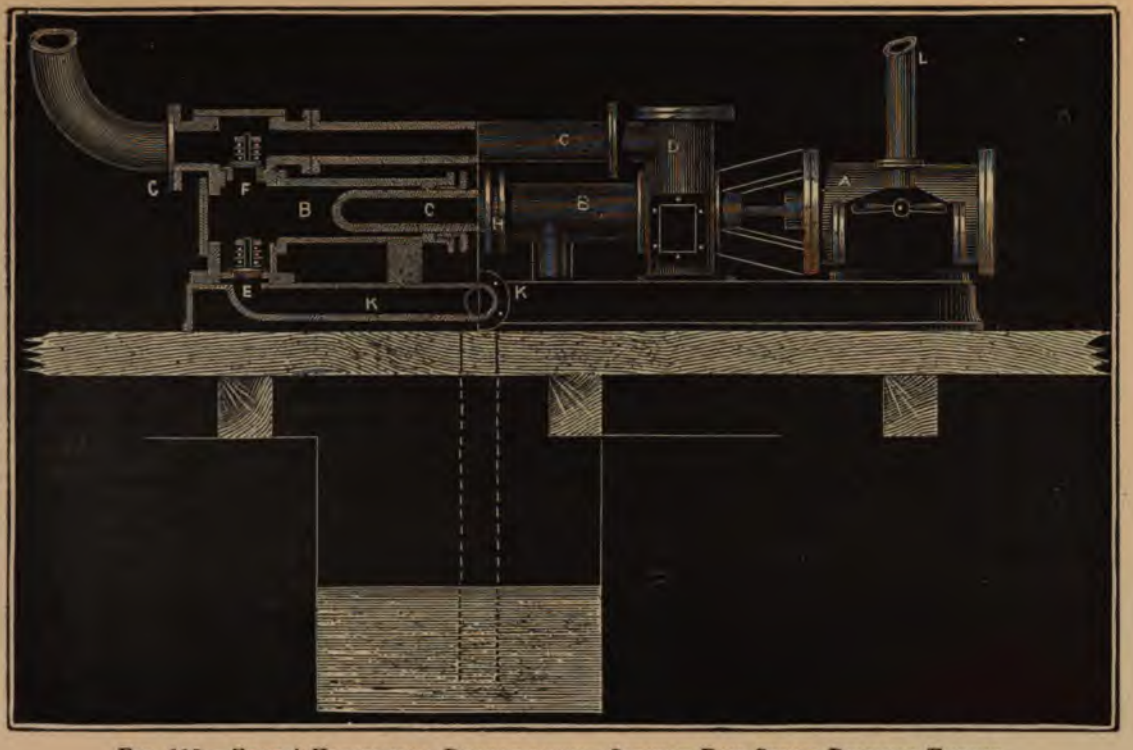
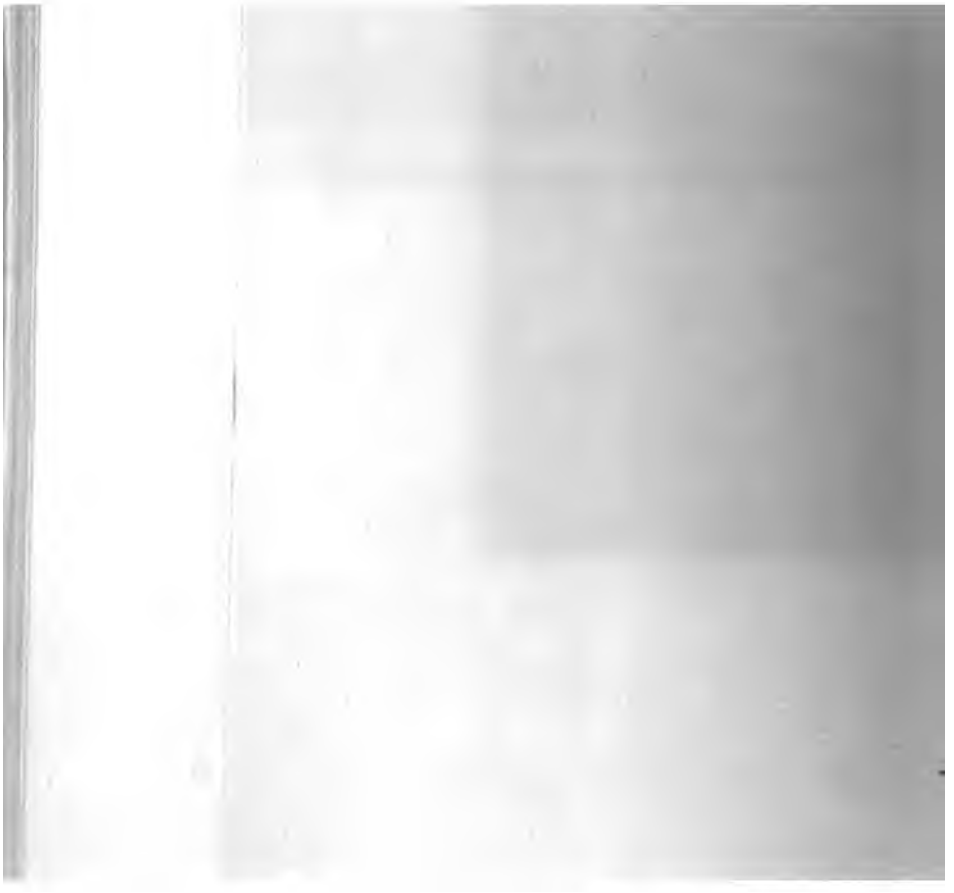


FIG. 115.—EVANS' HORIZONTAL DOUBLE-ACTING CORNISH RAM STEAM PUMPING ENGINE.



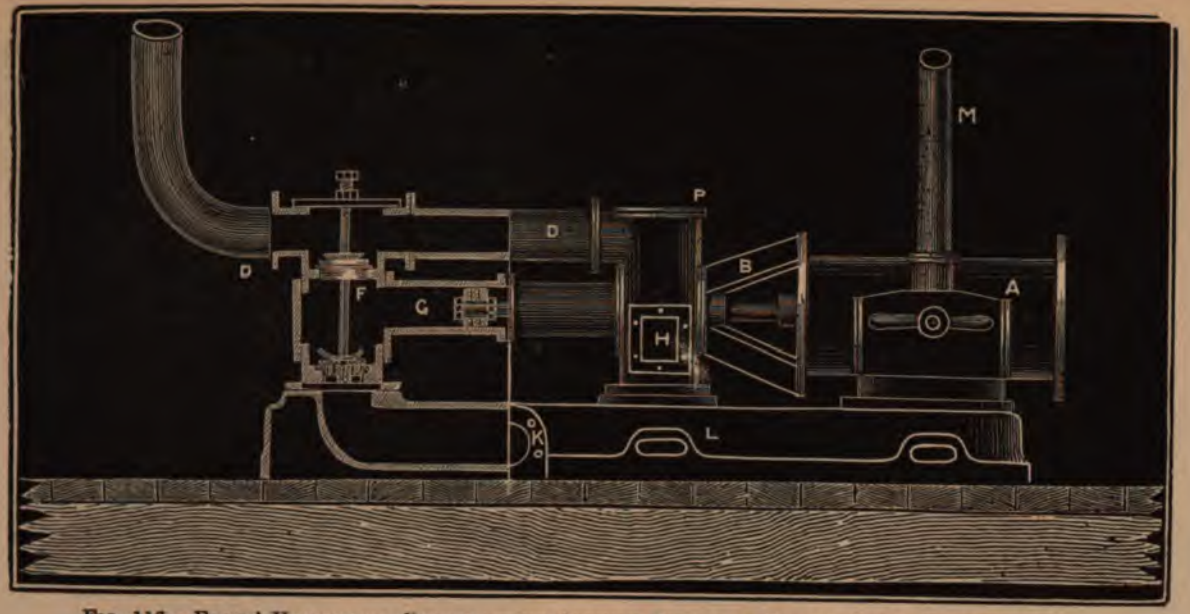
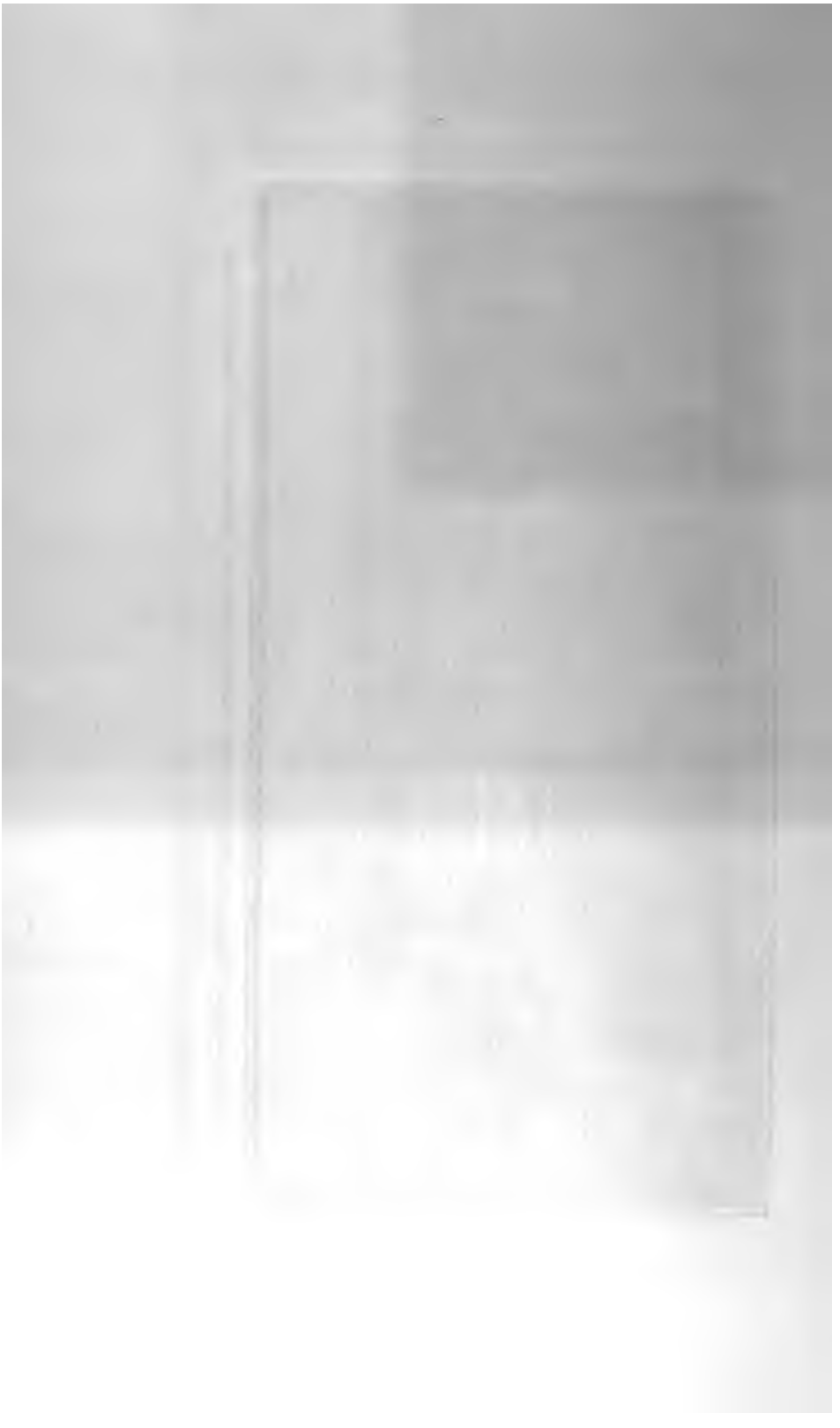


FIG. 116.—EVANS' HORIZONTAL DIRECT-ACTING CORNISH PISTON OR BUCKET STEAM PUMPING ENGINE.



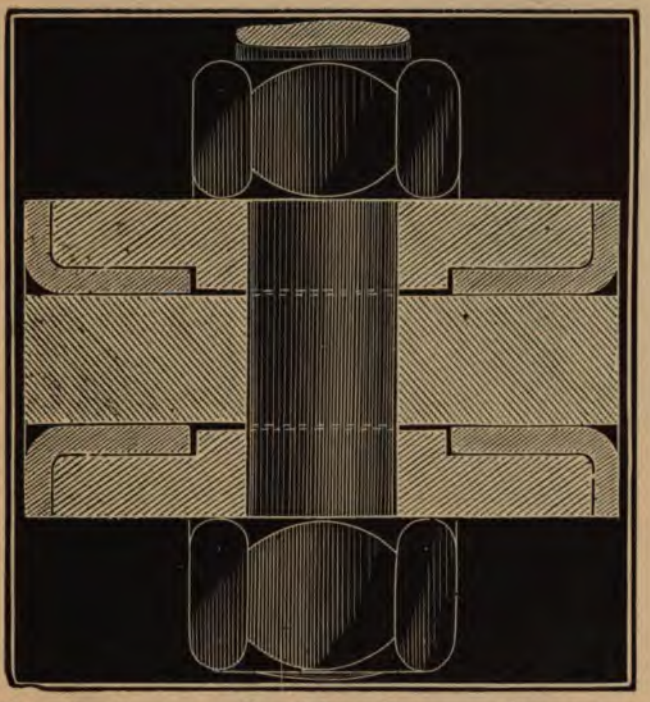


Fig. 117.—Section of Evans' Pump Piston or Bucket for Cornish Steam Pumps.



Fig. 118.—End Elevation of Evans' Pump Piston or Bucket for Cornish Steam Pumps.

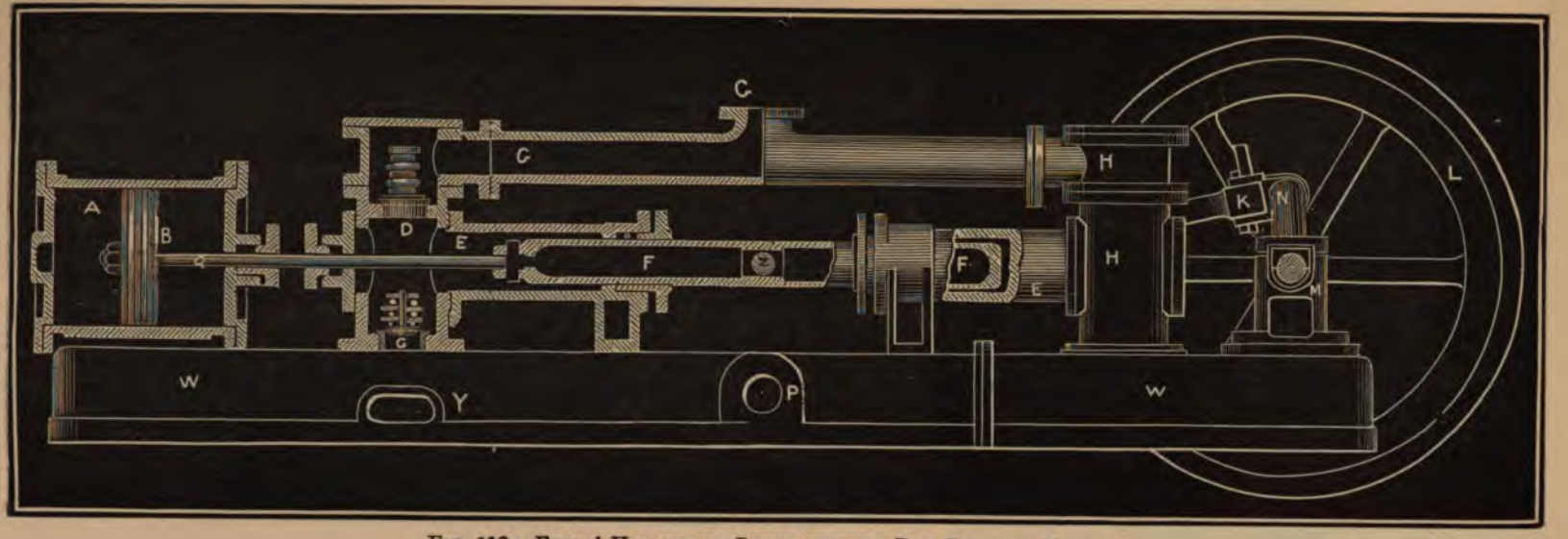


FIG. 119.—EVANS' HORIZONTAL DOUBLE-ACTING RAM PUMPING ENGINE.

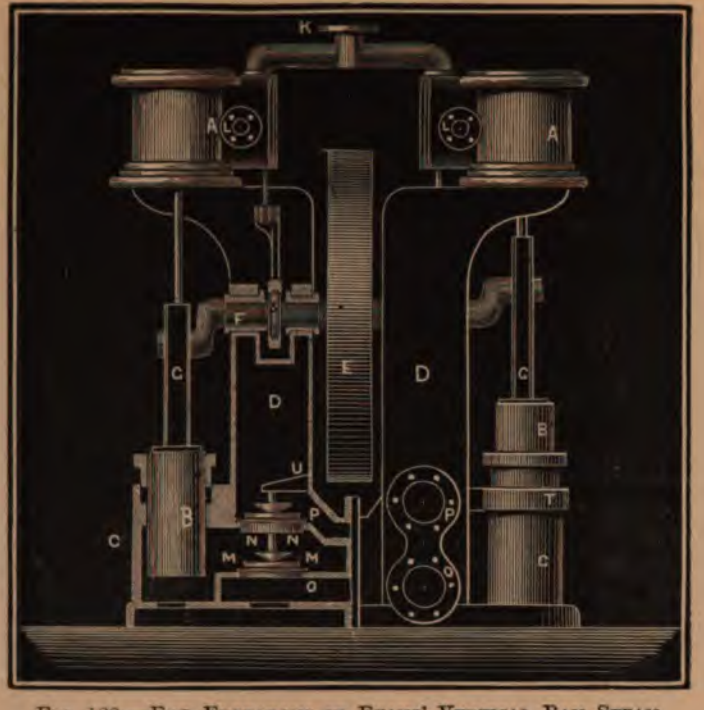


FIG. 120.—END ELEVATION OF EVANS' VERTICAL RAM STEAM PUMPING ENGINE WITH FLY-WHEEL.

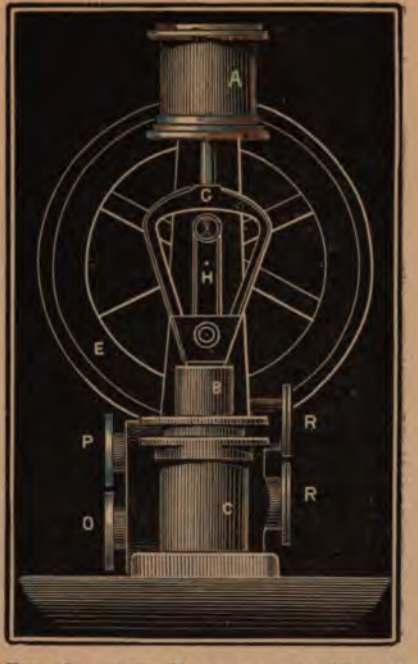


FIG. 121.—SIDE ELEVATION OF EVANS' VERTICAL RAM STEAM PUMPING ENGINE WITH FLY-WHEEL.

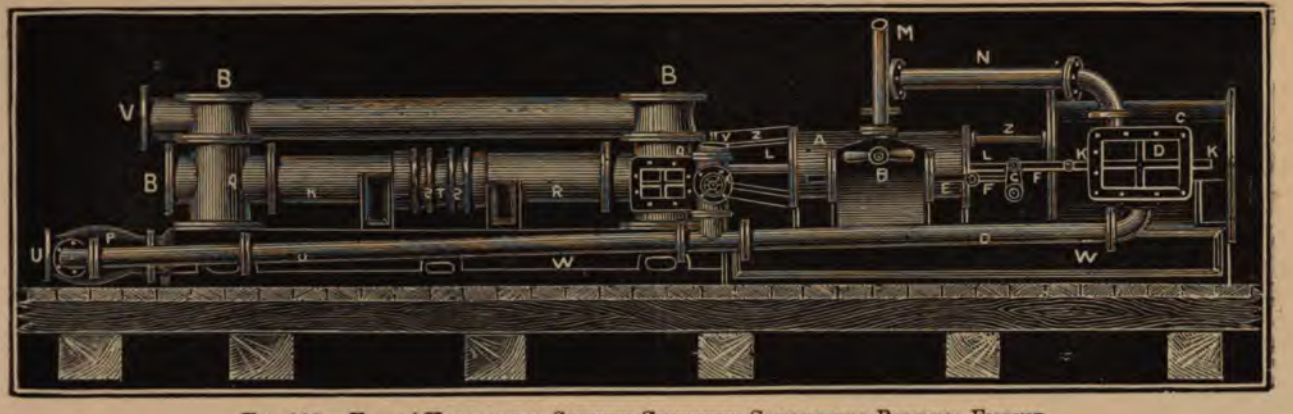


Fig. 122.—Evans' Horizontal Cornish Compound Condensing Pumping Engine.

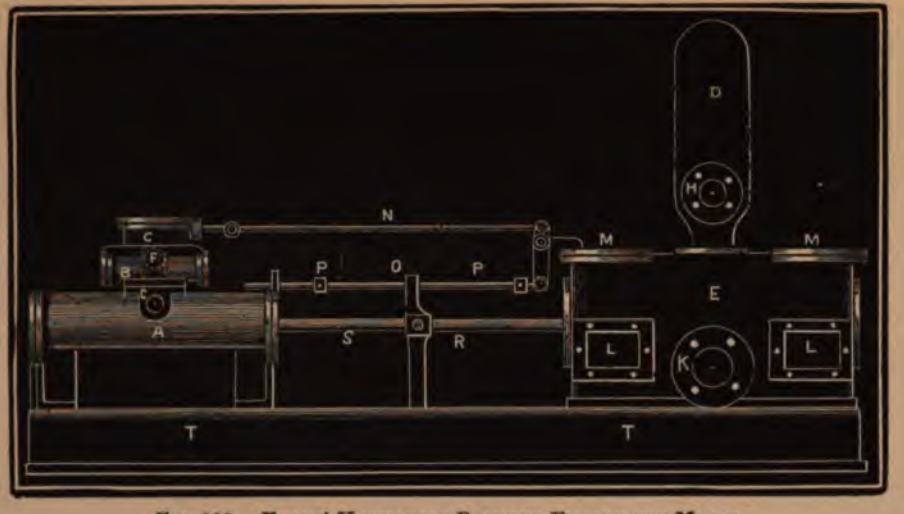
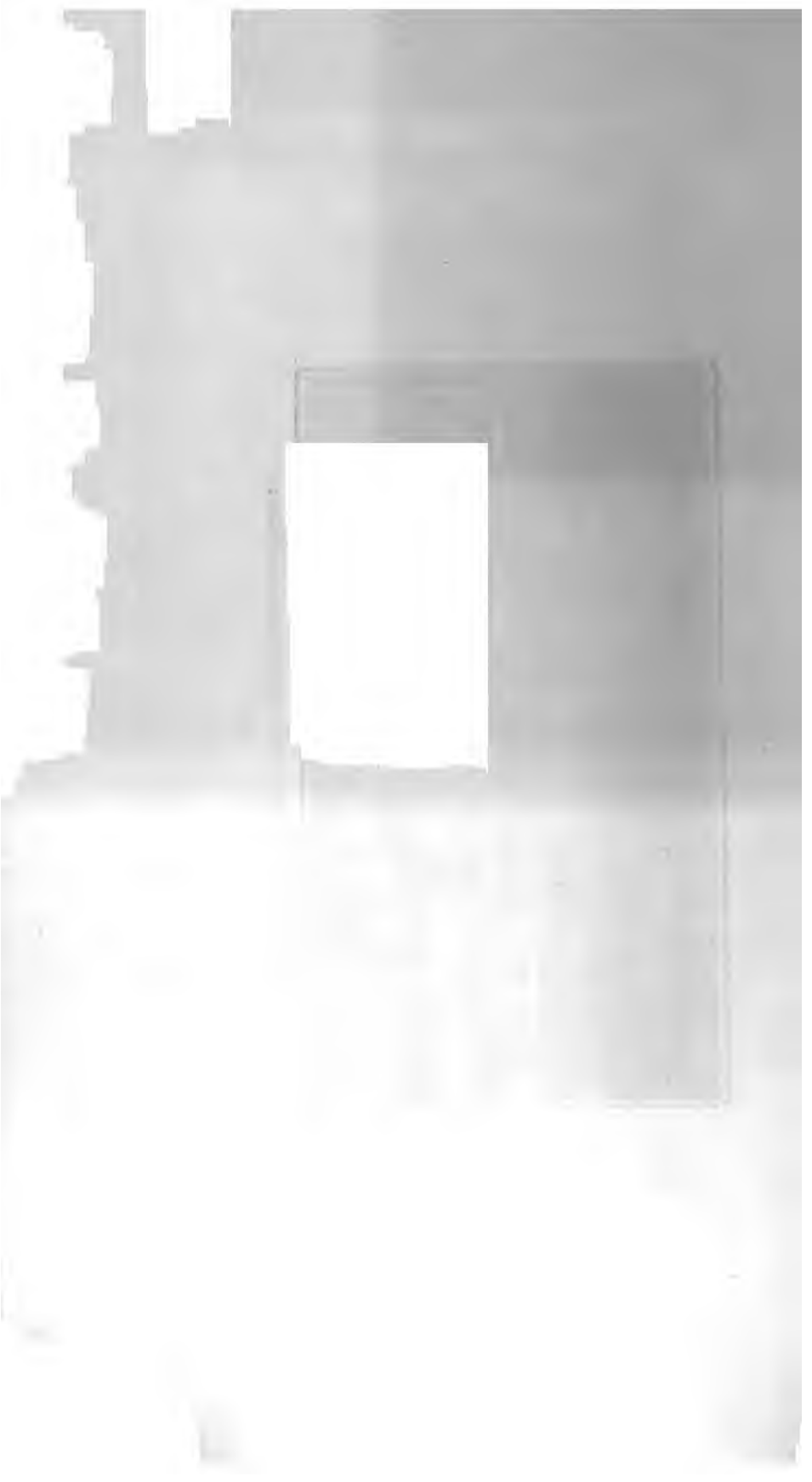


FIG. 123.—EVANS' HYDRAULIC PUMPING ENGINE FOR MINES.



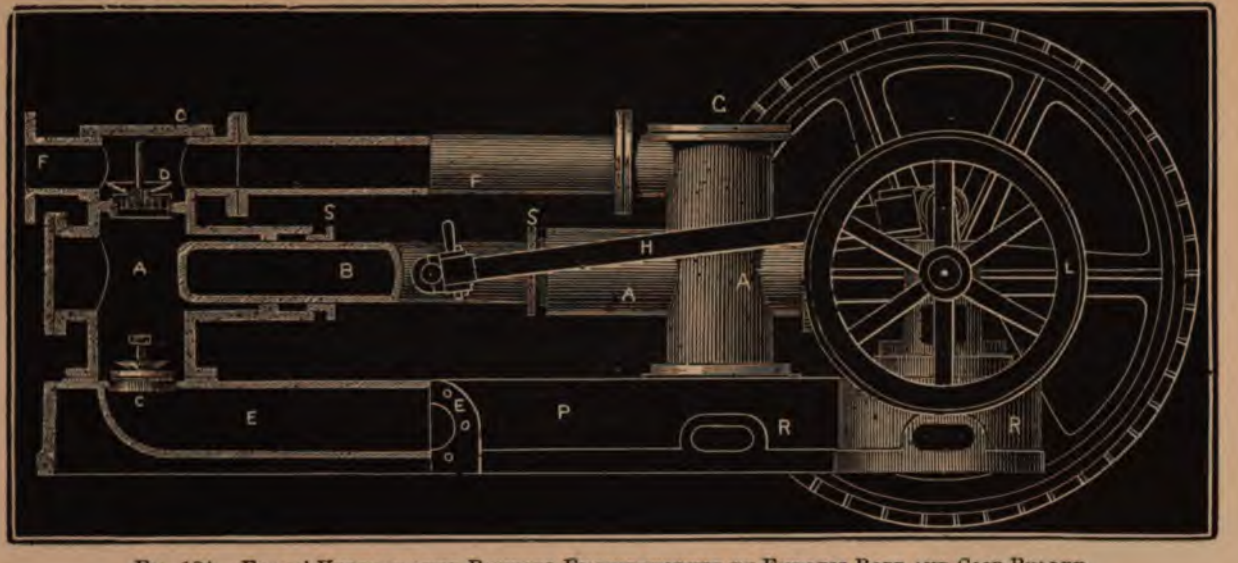
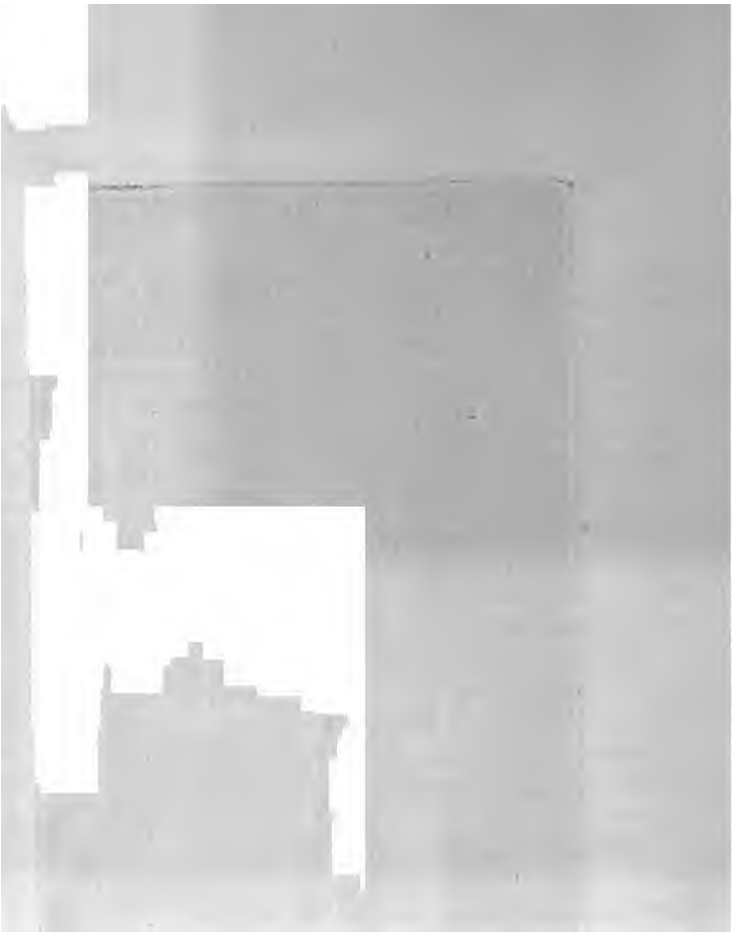


Fig. 124.—Evans' Underground Pumping Engine worked by Endless Rope and Clip Pulley.



S and S′, pump glands; T, pump ram; U, suction inlet; V, delivery pipe; W, foundation bed; X, blow-through valve; Y, exhaust to open air; Z, distance piece between high pressure cylinder and pump; Z′, tie bolts between high and low pressure cylinders.

A fair idea of an actual example of Evans's type of compound direct-acting Cornish steam pumping engine, calculated to raise 20,000 gallons an hour 450 ft. high with 35 lb. steam pressure per square inch at the pump, will be obtained from the following specification:—

The design of this engine to be horizontal, with high and low pressure cylinders arranged one behind the other, and generally known as "tandem," the pump being secured at the other end of same bed.

The high pressure cylinder to be 15 in. diameter by 36 in. stroke, carefully bored and flanges faced; bolt holes properly spaced to make a sound joint, connected to low pressure cylinder at the back of the latter, by a distance piece of ample strength to take the strain of the working independently of the bed.

The low pressure cylinder to be 30 in. in diameter by 36 in. stroke, carefully machined in the same manner as the high pressure cylinder.

Pistons to be truly turned and fitted to the respective cylinders, each to be provided with two cast-iron springs, carefully fitted, and of sufficient strength to maintain a tight working under the pressure of steam. The pistons to be firmly secured to the piston rod, which will be of best crucible steel, truly turned and fitted.

The stuffing boxes and glands to be bushed with phosphor bronze, each gland to be adjusted by bolts and nuts.

The cylinder covers to be part of distance pieces, and accurately turned and fitted to cylinders, with the bungs of ample size to admit of re-boring cylinders without re-turning of covers. The high pressure cylinder to be connected to pump chamber by strong distance piece.

The valve chest and valve to high pressure cylinder to be of the type known as "Tonkin's Patent," truly and accurately made, and provided with hand lever to move high pressure valve. The low pressure valve to be actuated by the high pressure gear, the two chests being in line.

The pump to be of the bucket type, double-acting, 9 in. bore and 36 in. stroke, and of a design of the very best form for high lifts, the chambers being cylindrical and therefore best suited to high pressures. The different parts are also so arranged that each separate one may be renewed in case of accident, thus avoiding the necessity of an entirely new pump end.

The bed to be of ample section to withstand the strain required, and to be in two parts for convenience of getting into position if necessary.

The valves to be of gunmetal, securely seated, and specially arranged for the lift by the insertion of rubber, gutta percha or wood in the upper portion.

Doors for access to be provided to all the pump valves and hand-holes where necessary, for convenience in inserting and screwing up bolts and nuts.

The bucket to be provided with best hydraulic leathers and screwed on to piston-rod as well as locked by nut.

All the joint faces to be machined to receive plain lead or other joints preferred, but the steam-chest cover will be made with canvas all over to form a perfectly true joint.

Approximate length, 16 ft. 6 in.; width in widest part, 4 ft.

The materials to be the best of their respective kinds and the workmanship to be of the best description throughout; all the castings to be sound and free from blowholes or other imperfections.

The foregoing specification refers to a bucket pump, and for a plunger ram would entail slightly greater cost, in return for which we have the advantages that the pump is more easily packed, and the wear of packing is less than with the bucket, and is preferred for dirty water and high lifts.

Fig. 123 illustrates a hydraulic pumping engine, as per the following particulars:—

A, motor cylinder; B, main valve chest; C, auxiliary valve chest; D, air vessel; E, pump; F, water inlet; G, water outlet; H, delivery; K, suction; L, suction valve doors; M, delivery valve doors; N, valve rod; O, tappet rod; P, tappets; R, crosshead; S, piston rod; T, bedplate; V, holes for holding down bolts.

It is not professed that for mines, water power in efficiency and economy will favourably compare with steam, but there are cases in which a certain amount of water power is available, and whatever percentage of this can be utilised is so much clear gain. For example in shafts main pumps cannot be fixed at every point where water is made. It is collected at the bottom, and in some cases a considerable quantity, representing a considerable power, has to fall from a considerable height. If not needed of course it is simply collected and raised to the surface. But there may be water made at a good distance from the shaft, but not much vertical depth below the bottom. Then such falling water may be used beneficially, avoiding the expense of steam however efficient, and the extravagance of compressed air.

An example exactly bearing upon this came under the writer's notice—indeed he was consulted about it immediately after the rough draft of this chapter had been prepared. In a mine having a shaft 200 yards deep, and at a point distant half-a-mile horizontally, and 100 feet vertically, from bottom of the shaft, water was made. The quantity was not large, but it had to be delivered into the sump, and the question was how to manage this. Manual labour would have necessitated relays of a dozen men each. Steam power would have required over half a mile of pipes, which meant enormous loss, and besides steam or exhaust was practically impossible. Compressed air would have involved even more loss than steam, besides the heavy expense of providing air-compressing engines on the surface, and pumping engine underground. A hydraulic pumping engine was evidently just the thing. Water could be taken either from the column of pipes in the shaft in which there was a pump, or conveyed from the surface in the event of the pump in the shaft not being at work. The power water on doing its work in the hydraulic pump, would be discharged into the delivery and returned along with the water made in the workings to the sump, whence the larger pump in the shaft would raise it to the surface.

Fig. 124 represents a pump worked without steam or water or compressed air. Possibly there is engine power in the mine more than sufficient for any haulage that has

to be done, and by means of an endless rope and a clip pulley power is transmitted if need be to a very great distance. At the Hargreaves Collieries, in Burnley, all the underground pumps are worked after this fashion, the only difference being that power is obtained from the endless chain. The principle is the same. The difference is that no clip pulley is used, the chain being simply coiled round an ordinary pulley sufficiently to exert the needful power. And a clip pulley is not an unmixed good, because all experience goes to show that ropes working in clip pulleys have shorter lives.

The letters of reference to the parts are as follow:—A, valve boxes and pump barrels; B, ram; C, suction valve; and D, delivery valve (patent rotating india-rubber disc with gun-metal grids); E, suction pipe; F, delivery pipe; G, doors for access to valves; H, connecting rod; K, crank; L, flywheel; M, clip pulley (Fowler's patent); N, bearings; P, bed-plate; R, hand-holes for threading bolts; S, packing glands; T, cross-head.

We now somewhat reluctantly pass away from the pumping machinery of Messrs. Joseph Evans and Sons, with a simple expression of the hope and the belief that in the future, as in the past, wherever pumps are used, their endeavours to produce efficient appliances will deserve and command success. It is very gratifying that whilst references were being made by the writer to these specialities, a high and impartial tribunal sitting in the foreign city of Amsterdam was awarding substantial honours in the same direction.



FIG. 125.—HYDRAULIC ENGINES PUMPING WATER OUT OF DIP WORKINGS TO SUMP.

[*To face page* 165.]

CHAPTER XVI.

PUMPING ENGINES AND APPLIANCES—DAVEY'S HYDRAULIC MACHINERY.

Hydraulic Engines pumping Water out of Dip Workings to Sump —Head of Water from the Surface enabling the Pump to empty the Dip Workings and its own Power Water into the Sump—Description of the Arrangement—Speed of Pump and Useful Effect—Arrangement for increasing or decreasing the Size of Pumps—Hydraulic Engines for pumping Brine from a deep Salt Mine—Head obtained by Accumulator placed at the Surface—Useful Effect—Special Application of Hydraulic Pump—Arrangement in which the same Pipe serves for the Driving Column and the Delivery Pipe—Air Vessels—Wipperman and Lewis's Automatic Pump for Supplying Air Vessels with Air—General Remarks on Pumping Engines and Appliances—Storage to be provided—Pumps should be equal to Double their Work—Position of Pumping Engine and Type of Engine to be used—The best Kind of Pumping Engine for the Surface is the Cornish or Compound Differential—The best for Underground Pumping is the Horizontal Double-Acting Long Stroke Ram Pumping Engine with Fly Wheel.

We again venture to just touch upon the pumping appliances of Mr. Henry Davey, of Leeds, who, not content with, or rather, perhaps, encouraged by the enormous success of his compound differential pumping engine, already described, has made a long and careful study of, and obtained considerable success with, his water pressure machinery for mines.

Figs. 125 to 130 represent various appliances which Mr. Davey has made peculiarly his own, and partially illustrate a paper read by him a little while ago. Fig. 125 illustrates a method of using water power to pump water out of a very long dip working, two engines being employed, namely A and B, each capable of raising 150

gallons per minute to 150 ft. height through 800 ft. of 7½ in. delivery pipes, C C, under an effective head in the driving column of 450 ft., this head being supplied through 1,900 ft. of 5 in. supply pipes, D D. In commencing to get out the water from the dip the first engine was placed as near as possible to the surface of the water. Suction pipes, E, were then added as the water was lowered, until a vertical depth of 25 ft. was reached. The second engine was then placed close down to the water level and the operation continued. In that way the pumping was uninterrupted, and a distance of 150 ft. down the dip could be reached before it became necessary to move either engine, the inclination of the dip being 1 in 6. The water delivered at the top of the dip workings is conducted to the sump, S, of the main pumping engines, and the water for driving the hydraulic engines is conveyed down the shaft from the surface of the mine; so that the main pumping engines have to pump the water delivered at the sump, which includes the water used in working the hydraulic engines. The exhaust water from the power cylinder is delivered direct into the rising main of the hydraulic pump, so that the hydraulic engines work with an effective head equal to the height of the supply cistern above the main engine sump, S. The engines have 2 ft. 6 in. stroke, with pump cylinder 8¾ in. diameter, and power cylinder 6¼ in. diameter. The usual speed o working is twelve strokes per minute = 60 lineal feet, and the useful effect obtained is 65 per cent. The pump is provided with a loose liner, by withdrawing which and putting in a larger piston, 12½ in. diameter, the capacity of the pump is doubled, enabling the engine to pump double the quantity of water to half the height. Of course such an arrangement would be found very convenient for increasing or decreasing the diameter of the pump according as the position was a greater or less vertical distance from where the water had to be delivered. Mr. Davey explains that these engines were specially designed for the purpose to which they were applied, it being important that they should be portable and occupy but little space; but in the majority of cases, especially where the engines are applied under considerable pressure, and where the water is at all dirty, he very properly



uses plungers in preference to pistons. In considering the arrangement just described and the absence of difficulty in its working, together with its really good useful result, the writer was forcibly reminded of a somewhat similar condition of things which gave a good deal of trouble and not a high useful effect a good many years ago, when hydraulic engines had not fought their way to the deserved popularity they have since attained. A pit some 200 yards deep had a pump in the shaft for raising a considerable quantity of water from the sump to the surface. Most of the coal having been got on the higher side, the pit became practically dependent on the dip workings, the inclination of which was the same as just mentioned, namely, 1 in 6, and considerably too much water was made to deal with it by means of water carts, which, even when equal to the work are rude in their action and play havoc with the roads. A pump was fixed to follow the workings down, or rather precede them, and deliver the water into the sump to be afterwards raised by the main pump to the surface. There was a hauling rope in the mine for direct haulage of coal, and it was first proposed, by means of a friction arrangement, to make this hauling rope work the pump, but as the haulage was very intermittent, and for other reasons, this never went beyond the region of proposal. Then an engine worked by steam was placed near the bottom of the shaft, and communication made to the pump by means of a clip pulley and an endless rope. The results were indifferent and a steam pump was fixed close to the water. Steam was conveyed in pipes from the surface boilers down the shaft into the mine, doing injury, causing annoyance, and producing woefully little useful effect, because, to commence with, the steam lost half its power on the way. Verily we live and learn in mining and in other matters, and whilst new difficulties arise in some directions, inconveniences experienced some twenty years ago need not now exist.

Fig. 126 illustrates an unusual and interesting arrangement representing a pair of engines with plungers applied under heavy pressure for pumping brine from a deep salt mine. Each hydraulic engine is capable of raising per minute 66 gallons of brine, 1,000 ft. high, with an effective

pressure of 560 lb. per square inch, in the accumulator, A, equivalent to 1,000 ft. head of brine. The rising and falling columns of the power water balance each other, and the head of the accumulator pressure exactly balances that of the brine in the rising main. The useful effect obtained with this arrangement is 59 per cent. Probably results just as good would in this case be obtained without the accumulator, and driving the pumps at the pit bottom direct by the pumps which are employed at the top for charging the accumulator, because these pumps were the measure of the power imparted to the engines below, and the accumulator simply acted as a regulator between these pumps and the engines at the pit bottom. The accumulator did not in this case at all fulfil the proper use of an accumulator, namely, to meet any sudden demand, which the pumps for the time of that demand were not able to cope with. It is only fair to say that Mr. Davey had nothing whatever to do with the accumulator nor the engines which supply it; his only was the hydraulic engine below, and almost certainly had the designs been his throughout no accumulator would have been attached.

Fig. 127 shows another application of a hydraulic pumping engine, which has proved so convenient as well as successful that several similar applications are in operation. A certain quantity of water comes out of the strata at a point, A, in a shaft where it is not convenient to place a pump, except at the bottom. This water, therefore, has to be taken down to the bottom before being forced to the surface. Under ordinary circumstances, in such cases the water is simply taken to the sump at the bottom, and all the work represented by this descent is lost, but in this case it is not so, and fig. 127, together with fig. 128, shows how the waste is avoided. The water is taken down from the point, A, in a down suction pipe, C C, to the hydraulic pump, B, and is delivered through the delivery pipe, D D, to the surface, so that the work done by the pumps is that due to the difference between 866 feet head in the delivery pipe and 502 feet in the down suction pipe, or to 364 feet only. The power cylinder, 6½ inches diameter, 1 foot 3 inches stroke, is actuated by means of a driving column from the point, E, having an effective pressure of 260 feet

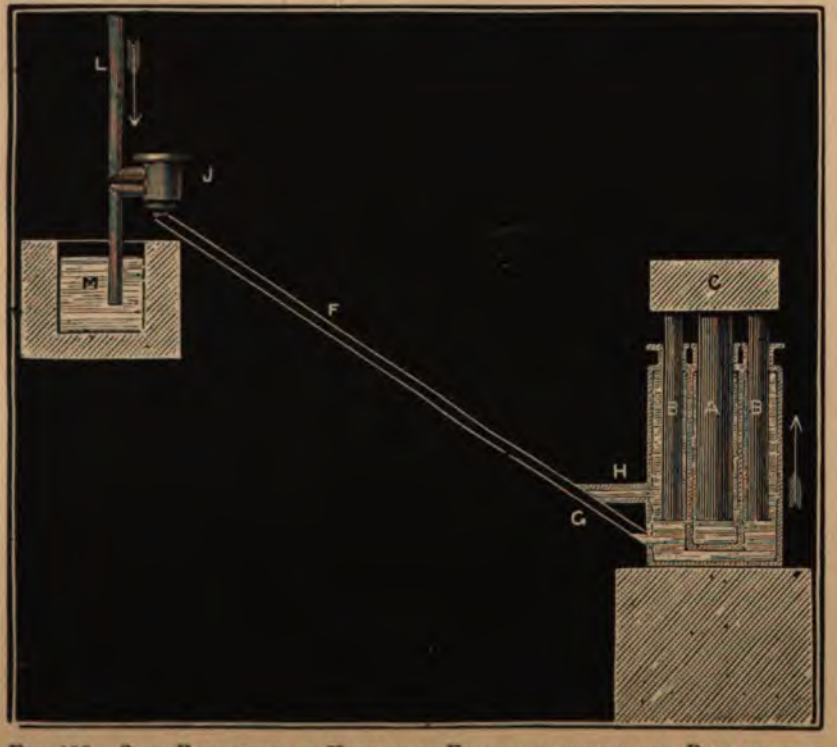


FIG. 129.—SIDE ELEVATION OF HYDRAULIC ENGINE IN WHICH ONE PIPE ANSWERS FOR DRIVING COLUMN AND DELIVERY.

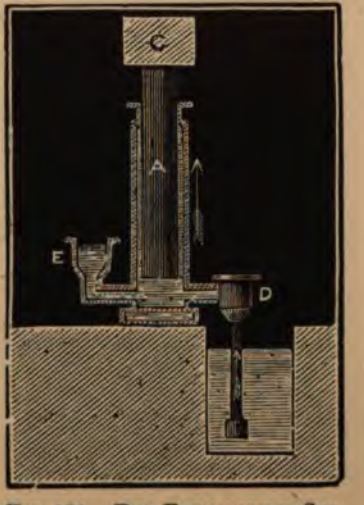


FIG. 130.—END ELEVATION IN SECTION OF HYDRAULIC ENGINE IN WHICH ONE PIPE ANSWERS FOR DRIVING COLUMN AND DELIVERY.

[*To face page* 169.]

head. The power cylinder and pumps are both single acting, but the pump is a piston pump of a peculiar construction. The pressure of the down suction column is constantly in the annular space between the piston rod 1⅜ inches diameter, and the inside of the pump barrel 4 inches diameter. (See fig. 128.) During the forward or delivery stroke of the pump, the pressure behind the annular area of the pump piston assists the plunger of the power cylinder, and the return stroke is produced entirely by the pressure from the down suction column being brought to bear on the full front area of the pump piston, the effective pressure for the return stroke being, therefore, that due to the difference between the full front area of the pump piston, and the annular area of its back face, or, in other words, to the area of the piston rod. This arrangement makes 10½ double strokes = 25 lineal feet per minute, and raises 7 gallons per minute, and produces a useful effect of 60 per cent. The driving water would run down to the shaft bottom in any case, so that all work represents so much clear gain.

Figs. 129 and 130 give sketch of a hydraulic engine in which the same pipe serves both for the driving column of the engine, and as the delivery pipe of the pump. A is the vertical pump plunger, and B B a pair of power plungers, all three coupled side by side to the same cross-head, C. D is the suction valve of the pump, and E the delivery valve. F is the pipe which serves both for the delivery from the pump and for the supply to the power cylinder. It is in connection with the power cylinders at G, and has a branch, H, connected to the delivery valve box above the delivery valve, E. The cross-head, C, is of sufficient weight to cause the descent of the three plungers against the head of water in the pipe, F. Water has to be pumped from the point, K, to the point, M. The power is obtained from the column, L. J is a single-acting valve box, somewhat common in good hydraulic engines, and has a change valve actuated through a tappet rod and wire by the rise and fall of the plungers. The mode of operation is as follows:—During the upstroke the plungers, B B, are being raised by means of the pressure in the driving column, L, and water is being drawn up into the pump cylinder, A, through the suction valve, D. On the

completion of the upstroke the change valve in the valve box, J, is reversed by the tappet rod and wire, and the other valves are also reversed by the water itself; so that the communication to the plungers, B B, from the driving column, L, is closed, and also the suction valve, D, belonging to the lower sump, K, while the delivery pipe to the upper sump, M, is opened. The weight of the cross-head, C, then causes the plungers to descend, forcing the water out of the pump and the power cylinders through the pipe, F, up into the sump, M, and the operation is repeated in the same way. The pipe, F, thus serves as a supply pipe to the engine during the upstroke, and as a delivery pipe from the pump during the return stroke. Such an arrangement is specially applicable to the draining of dip workings, but is not so portable as some other dip-working engines, and consequently can only be used to advantage in fixed positions.

Before concluding remarks on pumps mention should be made of air-vessels. It is something more than questionable whether for pumping engines underground, double acting and working against high columns, air vessels are an improvement; but wherever applied, it is essential that they should be kept uniformly charged with air. To have them sometimes nearly full of air, and at other times full of water, all the air having been absorbed, makes it very probable that the air vessel will burst with the varying shock, and even if strong enough, as when made of wrought iron, to resist almost any strain, the effect on the working of the pump is bad.

The writer had unpleasant experiences of this kind with a pumping engine working against some 300 pounds pressure; the engine worked irregularly, and more than one air-vessel was destroyed. In searching for a remedy a very excellent contrivance known as Wipperman and Lewis's automatic pump for supplying air-vessels with air came under his notice. It consists of a cylindrical vessel having no working parts, the water itself forming the piston. At the bottom of this cylindrical vessel is a small pipe fitted with a regulating cock, and this pipe is attached to the pump valve box immediately below the delivery valve. At the top of the cylindrical vessel is fixed a small gun metal valve box, fitted with inlet and

outlet air valves, and from this a delivery pipe communicates directly to the air vessel. There is thus a communication between the top of this appliance and the pump air vessel, and between the bottom of the appliance and the pump valve box. The action is somewhat as follows:—When the pump draws its water it partly empties the cylindrical vessel, a gauge attached on the outside showing to what extent; and the amount can be regulated by the regulating cock already mentioned.

On the return stroke of the pump, whatever air has been drawn into the appliance—and this, again, is regulated by the amount of water drawn out—is delivered into the air vessel, and in this way the quantity of air in the air vessel can be kept constant.

The special advantages are—the supply of air can be regulated to a nicety, and there is no friction, because there are no working parts. The appliance is noiseless in action and easily attached, and of late years has been largely adopted.

Such comprises our section on pumping machinery; and whilst it has not been possible or desirable to refer to all the various kinds of successful pumps now in use, there has been no attack made upon any class, and those which have been described and illustrated may not unfairly be taken as fairly representative of pumping appliances, ancient and modern.

In concluding the chapters on pumping engines and appliances, one or two, not instructions exactly, but rather recommendations, may be repeated and impressed. Storage amounting at least to several days' make of water, and, if possible, several weeks, should be provided, because pumping arrangements, however good, get out of order; and although generally such derangements may be corrected in a few hours, a serious mishap sometimes comes which stops a colliery a week or two. If the storage is insufficient we flood the mine, doing immediate damage, and entailing expense to draw the water out afterwards. But if there is abundant storage, then when pumping resumes we simply work the pump continuously till all the accumulated water has been got out.

Pumps should be equal easily to double their work, that is, supposing we had 1,000,000 gallons to raise each

24 hours, our pumping arrangements should be such as working at an average speed can deal with 83,333, or, say, 84,000 gallons per hour, thus raising in twelve hours all the water made in 24.

In this way mishaps may be made almost impossible, because the pumps are never overworked, and there is always a period each day for thorough examination and slight repairs, or, if pressed for power to generate steam, the same boilers can do the winding and hauling at one time and the pumping at another. Then as to where the pumping engine should be placed. If the mine is very heavily watered—that is, when we measure the amount of water made each day in millions or fractions of millions—and if there is danger of the mine being flooded and the pump being drowned, the pumping engine should be upon the surface; and although the Cornish pumping engine is an old and tried friend, the compound condensing differential pumping engine has all the advantages of the Cornish, and, in addition, gives us a higher grade of expansion with less variation of strain, a higher average with a lower maximum speed, makes disasters from mis-strokes impossible, and being horizontal, requires less massive foundations, and can be fixed nearly anywhere. When the mine is not heavily watered, and there is no fear of flooding the mine or drowning the pump, by all means place the engine underground. We dispense with pump-rods, and can make smaller machinery do the work, because it can work much more quickly. In all cases where pumps are placed underground, and steam is the motive power, condensers should be applied, by which exhaust steam is diverted into the suction pipes. Where room is very limited, which is often the case below ground, the Special type is found convenient. Where there is plenty of height, a vertical pump can be fixed, and is deservedly popular. But probably the best arrangement for underground pumping is a pair of horizontal double-acting long-stroke ram pumping engines, and so designed that although usually working together, can be disconnected, and each engine separately capable of working against the lift, and, of course, having circular motions and substantial fly-wheels.

There is no design which brings the machinery of the engine so completely under the eye of the man in charge



as the horizontal, and no mechanism which so beautifully reverses the motion, breaks the shock at the beginning and end of the stroke, and so accurately determines the exact stroke, as the circular motion, comprising the crank, the connecting rod, and the fly-wheel.

There are many instances where it is necessary to adopt the use of a pump in a dip-working which has to be worked by manual power, in which case it is very necessary that it should be so constructed that it does not stand high or require a long swinging lever, which, when the workings are low, so that the men cannot well get at it upright, it is needful that something should be applied with a rotary motion and placed horizontally. These requirements and conditions have been well met by the firm of John Warner and Sons, of the Crescent Foundry, Cripplegate, London, and Walton-on-the-Naze, in their rotary hand miners' pump, which is mounted on a strong frame, having a double-action piston pump, with the valves large and easy of access, the piston rod being geared up with spur wheels to the crank shaft to ensure ease of manipulation for one or two men working. These pumps have been much in favour in the Durham colliery district and other localities where the treble ram horse or pony power pumps (fig. 130*a*) of the same firm are in use, and are celebrated for larger workings and more permanent positions to raise the water to the main sumps or pumps at the pit's mouth. Nothing could be more suited to the requirements in very many cases than this class of machine, which, being very portable and sufficiently narrow, can be passed along the workings on the tram rails laid for the transport of the mineral with a small horse or pony to work it at its destination, and, as the cutting progresses, to keep it near to the face and the dip free from water. These pumps—which will pass grit and sludge, and are exceedingly handy for access to the valves, steady working without jerks, easy to keep tight in the packing, not liable to choke or grind out the valves or rams with grit, whilst being always complete and compact, ready to start so soon as the pipes are connected, of a low horizontal form, and easily stowed away in a corner of the working—naturally have many advan-

tages, and by the experiences of many have been proved an acquisition in colliery workings.

It is only reasonable to suppose that having a form or type of pump which had been proved to be the very thing for the requirements of dip workings, even if the work to be performed might be better dealt with by steam power direct or with wire rope transmission, that that type should be adopted with the other power and application in the place of horses, and, as a consequence, we find that Messrs. Warner, fully alive to these requirements, were ready to meet them when necessary, so that they point to at least seven instances where their treble ram pumps have been applied successfully with wire rope-power transmission—in the Gloucester, Cheshire, Durham, and Scotch districts, lifting, as in the remarkable case at the Springwell Colliery, near Gateshead, to no less a vertical height than 600 feet, and that through two miles of pipes, at the rate of 120 gallons per minute, with a very small cost of £10 in four years for replacements of valves and other points of maintenance.

The fact of these pumps being geared to suit the speed of the rope traverse, working noiselessly without jerks by having a treble throw, and the opportunity being afforded to detect the leaks, if any, of the packings which are at the glands, so that there cannot well be a bye pass, points to success in working, as the repair cost does to economy.

These pumps have been very successfully applied for both high and low lifts, with fast running steam engines geared down to run the pumps at a moderate or slow speed with great success, so that it may be very well said that Warner's treble ram pumps are very suitable for every application of power in pit workings, it having been so demonstrated as to be beyond the region of experiment, by actual and practical working.

A very useful form of direct action steam pump, of a vertical form for slinging in a shaft for sinking purposes, or for permanent pumping, has recently been introduced by the same firm under the registered title of "the Favorite" (Fig. 130*b*) which has been adopted for the Chinese Government, and which has not only the advantages of being easily slung and occupying small space in the sinkings, but is so arranged that the exhaust steam is condensed,

and is carried forward with the water to be pumped through the suction pipe, this being an arrangement of great value in pits, saving an immense amount of dampness in the air, which it is at all times difficult to get rid of, and is the subject of a patent by a Mr. R. Rackham, who has had considerable experience in large pumping machinery. The same class of pumps is also adapted to dip workings and can be provided with cylinders proportioned to suit any lift, and mounted upon a low carriage can be moved forward as the workings proceed (fig. 130*c*), or as Messrs. Warner show by their illustrations, the same pump can be applied for reclaiming drowned-out workings. (Fig. 130*d*.)

The horizontal direct-action pumps of this firm are made of both piston and double action ram type, the former for moderate and the latter for high lifts; with the latter the leakage, if any, is easily detected by the outside glands which can be readily screwed up and adjusted in a very short space of time; for steam boiler feeders they have a speciality in the form of a handy ram pump working vertically, mounted upon a good base, and provided with a fly-wheel into which a hand lever may be screwed, so as to work it by hand if, and when, required. To mention the whole of the many forms of pumping machinery manufactured by this firm would form a book of itself as their catalogue does, especially when to their pumps they add their various designs of boring tools and other mining machinery, for which they are well known and celebrated, having a world-wide reputation and business connection, formed during the last century or more of years now past in the business they follow.

CHAPTER XVII.

MINING MACHINERY AT WHITEHAVEN IN 1806.

Mr. John Henry Harden, of Phœnixville, Pennsylvania—Mr. John B. Longmere, of Whitehaven—William, Lord Lowther—Scalegill New Collieries—Particulars of Borings—Steam Engines—William Pit Rotative Machine—Description and Illustrations of the various Parts—William Pit Temporary Pumping Engine—Description and Illustrations of the several Parts—How Steam is generated in the Boiler—How the Engine is started and how it Works—Description of an Atmospheric Engine—A Double-powered Atmospheric Engine with two Cylinders—Particulars of the Winding Appliances—Depth of Pit and Period of a Winding—Load raised—Probable Power of Winding Engine—Comparison between the Whitehaven Engine and Modern Winding Engines—Probable Power of Pumping Engine—Size of Pump, Height of Lift, and Quantity of Water.

Whilst the writer was dealing with that portion of pumping engines and appliances which refers to a very early period, commencing even before the Christian era, a constant reader and frequent correspondent, and an excellent friend of the writer, although never seen by him—namely, Mr. John Henry Harden, of Phœnixville, Pennsylvania—was good enough to forward a communication, which was afterwards published. He referred to a work which had come into his possession, and referring as it did to mines and mining operations nearly a century ago in one of the coalfields of England—namely Whitehaven—a coalfield then, and a coalfield now—he thought, containing as it did some excellent illustrations, and much evidently reliable matter, it might form an interesting link between appliances of past times and those of to-day. This communication was copied into many contemporary papers, and attracted considerable attention in Cumber-

land and in the North generally, and Mr. Harden very kindly placed the work in the writer's hands to make such use of its contents as he should think fit. Being appropriate to the subject of *The Mechanical Engineering of Collieries*, and having roused so much attention in mining districts, the writer decided to place so much of its contents as belonged to mechanical appliances before his readers. Accordingly, seven illustrations of winding and pumping machinery (see figs. 131 to 137) have been re-produced which, although not perhaps got up with the clearness and excellence of the original coloured drawings, it is hoped will clearly enough show the principle and construction. Also the text, so far as needful to explain the drawings, has been taken practically as found in the manuscript. The author, Mr. John B. Longmere, is a little astray in one or two points, as, for example, where he speaks of one cubic inch of water at atmospheric pressure being transformed at a temperature of 212 degs. into 800 cubic inches of steam. But generally, Mr. Longmere would appear to have been an unusually well informed man, and a very competent all-round mining engineer. To Mr. Harden we must simply tender our thanks for so generously placing at our disposal such good and interesting information as to appliances which would appear to have been amongst the most efficient of their time—nearly 100 years ago. We may mention that the title page reads, "A Short Account of the Present System of Coal Mining, to which is added an account of Scalegill Collieries, William Pit Machines, and Overend Limekilns." And the dedication page reads, "The following Drawings and Observations relative to the Present System of Coal Mining, Part of the Coal Works, Engines and Lime Works, in the vicinity of Whitehaven, are most humbly addressed to the Right Honourable William, Lord Lowther by his Lordship's most respectful and devoted servant, John H. Longmere, Whitehaven, 24 June, 1808."

A plan showing the various royalties and properties marks those of Lord Lonsdale, William Wilson, Dixon, Johnstone, Hartley, Patrickson, Scott, and Scalegill Hall, Woodend and Lundhouse. The river Poe is shown, and, in addition to Scalegill Collieries, we have Parti's Pit.

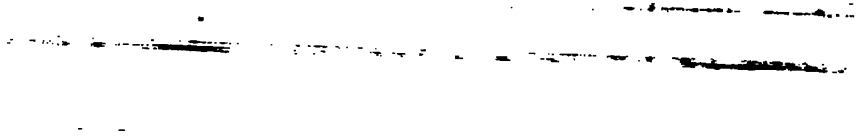
Scalegill New Colliery.

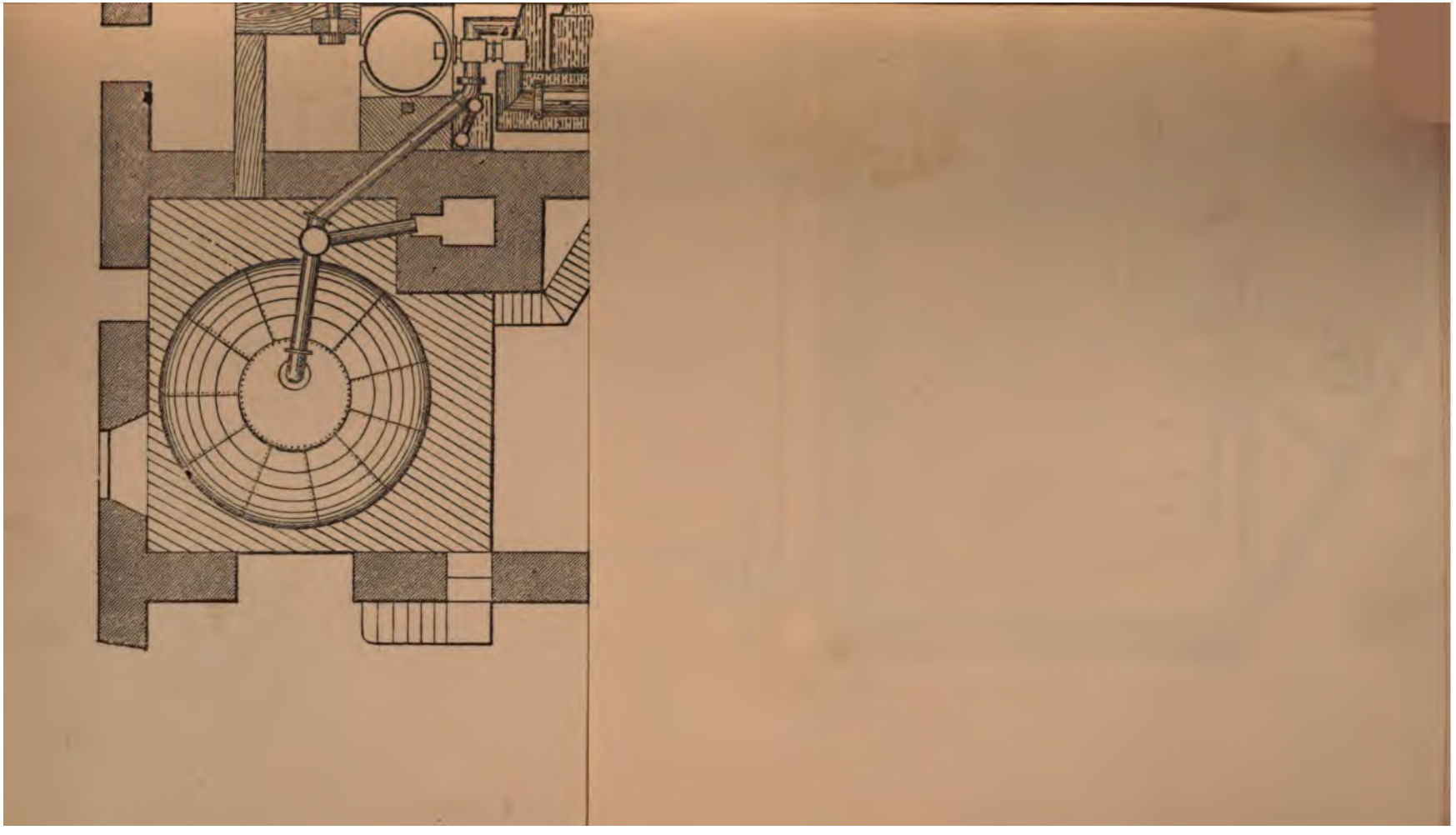
Trial Holes.—June 30th, 1806, began to search for coal at Holehouse at borehole No. 1. This hole was bored 34½ fathoms. In that distance five workable seams were found, the last and largest of which was 4 ft. 11 in. thick. It is called the six quarters seam of coal. The rest were from 2 ft. 6 in. to 3 ft. 6 in. in thickness. The second trial hole was where Henry pit now is; it was bored 8 fathoms to the main seam of coal 9 ft. high. The third trial hole was bored 34 fathoms. Four seams of coal, each about 1 yard thick, were met with. They all lay below the main band. The fourth trial hole was bored about 20 fathoms, in Holehouse garden, but no coal was met with in that distance. The fifth trial hole was made where Elizabeth pit is sunk. It was bored 15¾ fathoms to the main seam 12 ft. high. The sixth trial hole was bored 12½ fathoms to a yard seam. The seventh trial hole found a yard seam at 8 fathoms. The eighth trial hole was bored 31 fathoms, but found no workable seam.

Henry Pit.—This was the first pit sunk at Scalegill New Colliery. It is 9 fathoms to the main band, 17 fathoms to the yard band on the upcast side, 20 fathoms to the yard band on the downcast side. The seams of coal in this pit dip to the south one yard in four. The main seam of coal is 9 ft. high.

Elizabeth Pit.—This pit is 16¾ fathoms to the main band which is 12 feet high. The pit is sunk 19 fathoms below the main band. At 10 fathoms the first yard band was met with, and at 15 fathoms a very strong feeder of inflammable air coming out from the joints of the freestone strata, it was conjectured that a seam of coal was not far below. A borehole was put down 4 fathoms, and a seam found 4½ ft. thick. As the inflammable air was so strong, the pit was stopped from being sunk any further, to give it time to exhaust itself partly. The pit has been stopped about half a year, but there is not much difference in the strength of the inflammable air.

Steam Engines.—These machines act either by the force of the temporary elastic vapour of water or steam, or by the pressure of the atmosphere.





Steam engines, having steam as a first mover, are brought to great perfection by Mr. James Watt and other engineers adopting his principle, while those engines that act by the pressure of the atmosphere were, till of late, left unimproved, no one thinking them worthy of attention. The following rotative machine and pumping engine are the greatest attempts to carry this principle to any degree of perfection. (See figs. 131 to 137.)

When water is heated to a great degree it passes into an elastic vapour or steam. This vapour preserves its elasticity as long as it is kept at the temperature that it passed from water into vapour, but if it be cooled below that temperature it resumes its former state of water. It is therefore called a temporary elastic vapour.

When it is generated at 212 degs. of Fahrenheit's thermometer it is about 800 (?) times as rare as water. Steam, then, from one cubic inch of water will occupy a space of 800 cubic inches (?) If this was included in a vessel, and a jet of cold water introduced into it, the steam would instantly be condensed, and a partial vacuum made.

In one of the atmospheric engines steam is made to fill the cylinder. It is then condensed, and a vacuum made under the piston. The air then acts by its pressure upon the piston with a power nearly equal to 15 lb. upon every square inch, and forces it down to the bottom of the cylinder.

In pumping engines, or others requiring power only at one part of the stroke, one cylinder is used, but in a complete double-powered atmospheric engine two cylinders are used, one at each end of the regulator beam, and the air acts upon their pistons alternately.

William Pit Rotative Machine (see figs. 131, 132, 133, 134) is a double-powered atmospheric, and comprises the following parts:—

1. The boiler, 13 ft. diameter and 10 ft. high.
2. The chimney, 3 ft. square within, 7 ft. without, and 62 ft. high.
3. The steam pipe from the boiler to the steam cylinder.
4. The safety valve and pipe for letting the overplus steam from the boiler into the chimney.

5. The steam cylinder 44 in. diameter; the stroke of the piston 3 ft. 8 in.

6. The branch pipe between the cylinder bottom and the nozzles.

7. The steam nozzle connected with the branch pipe to the cylinder at its lower end, and the steam pipe at its upper end; there is a brass valve fixed in the nozzle about half-way between these pipes.

8. The exhausting nozzle with a valve of the same dimensions as the other fixed at the lower end.

9. The condenser; it is 6 ft. long and 16 in. diameter; it is immersed in a cistern of cold water.

10. The cold cylinder 28½ in. diameter; the stroke of the piston 4 ft. 9 in. long; this cylinder is immersed in a cistern full of cold water, and there is always a vacuum under its piston.

11. The communication pipe between the condenser and cold cylinder.

12 and 13. Two injection valves; through the first the water jets horizontally into the condenser, and through the other perpendicularly into the cylinder.

14. The eduction pipe from the bottom of the cylinder; it conveys the injected water and air to the foot of the air pump.

15. The blow valve.

16. The air pump, 18 in. diameter, having a stroke of 2 ft. 9 in.; the air pump draws the hot water and air out of the condensers, &c., and maintains a more complete vacuum than could be done without it.

17. The delivery cistern of the air pump; the hot water that the air pump delivers is collected into this cistern, and part of it is lifted by the pump to supply the boiler, and the rest is conveyed away by the troughs.

18. The cistern the condenser is immersed in.

19. The great cistern that holds the cold cylinder.

20. A cistern that holds water to cover the blow valve.

21. The cold water pump, 7 in. diameter, having a 2½ ft. stroke; it draws water from the one cistern into the other cistern.

22. The cistern communicating with the reservoir by means of iron pipes; it is always full of water.

23. A little cistern, having a pump 4 in. diameter and

12 in. stroke; it draws water to feed the boiler; the cistern has its supply from the delivery cistern of the air pump by means of a pipe lying between them.

24. Two strong pieces of wood standing upright, to which are fixed two iron guides for preserving the piston rod perpendicular.

25 and 26. The fly-wheel, 20 ft. diameter.

27. The rope barrel wedged upon the fly-wheel shaft; it is 9 ft. in diameter and 6 ft. broad.

28. Strong pieces of wood wedged in to support the walls of the work.

29. The trough that conveys the hot water back to the reservoir.

30. The regulator beam, 20 ft. long and 20 by 21 in. square.

31. The strong cast-iron connecting rod fastened to the regulator beam at the high end by means of a joint, and at the lower end to the crank.

32. The crank, 2 ft. 9 in. long.

33. Parallel links.

35. The boiler pump and cistern.

36. The piston pipe, having a cock at its end to regulate the feed of water upon the piston.

37, 38. The boiler feed-pipe and cistern. At the bottom of the cistern there is a valve fixed and worked by a small iron beam. To the other end of this iron beam there is a strong wire fixed. This wire goes through the boiler top, and has a buoy fixed to its lower end. When the surface of the water in the boiler is of a proper height the valve at the bottom of the cistern is shut, but when it is lowered by the evaporation of the water, the buoy floating on its surface is lowered too. It therefore lifts that end of the beam to which the valve is hung, and by raising the valve permits the water out of the cistern to descend down into the boiler until the surface of the water be so high as again to shut the valve by raising the buoy.

41. The iron beam fixed to the safety valve that regulates the strength of the steam.

42. The plug frame that hangs by a strong iron rod to the regulator beam; it works the air pump and the hand gear.

43. Uprights, to which guides are fixed to cause the plug frame to work perpendicularly.

44, 45. Two iron beams connected with the hand gear to open and shut the valves in the nozzles.

46. Two beams that open and shut the injection valves.

47. The cold water pump beam.

48. The boiler pump beam.

49, 50. Two strong screw bolts to screw the beams firmly to the stonework.

51. The air-pump foot nozzle wherein is fixed the lower valve of the air-pump.

52. The arch head upon the regulator beam is to keep the piston rod of the cylinder always perpendicular.

53. The chains that connect the regulator beam with the piston rod of the cylinder.

54. The catch pin; it goes through the head of the beam, and its ends project out, as is shown by fig. 133. When the engine makes by accident a longer stroke than usual it rests upon the beam before the piston can touch the bottom of the cylinder, and by that means prevents its breaking the cylinder bottom.

The boiler being half filled with water, a strong fire is made underneath it. After the water is heated to the boiling point, those particles at the bottom and sides of the boiler begin to evaporate, rise through the water in the state of a vapour, and throw it into a violent agitation—in other words, the heat at the bottom and sides of the vessel removes the particles of the water to a greater distance and diminishes the cohesive power. In this state they rise through the water. When a sufficient quantity of vapour or steam is collected, and the engine is set forward, the steam valve and exhaustion valve are opened, the steam from the boilers enters and fills the cylinders, the condenser, and the eduction pipe, and expels the air at the blow valve; then the valve is shut, and jets of cold water enter at the other valves and condense the steam in the condensers and cylinders, by which means a vacuum is made in the condenser and under the piston of one cylinder, the atmosphere acts by its pressure on that piston, while at the same time the exhaust valve being shut, and the steam valve opened, the steam on the under

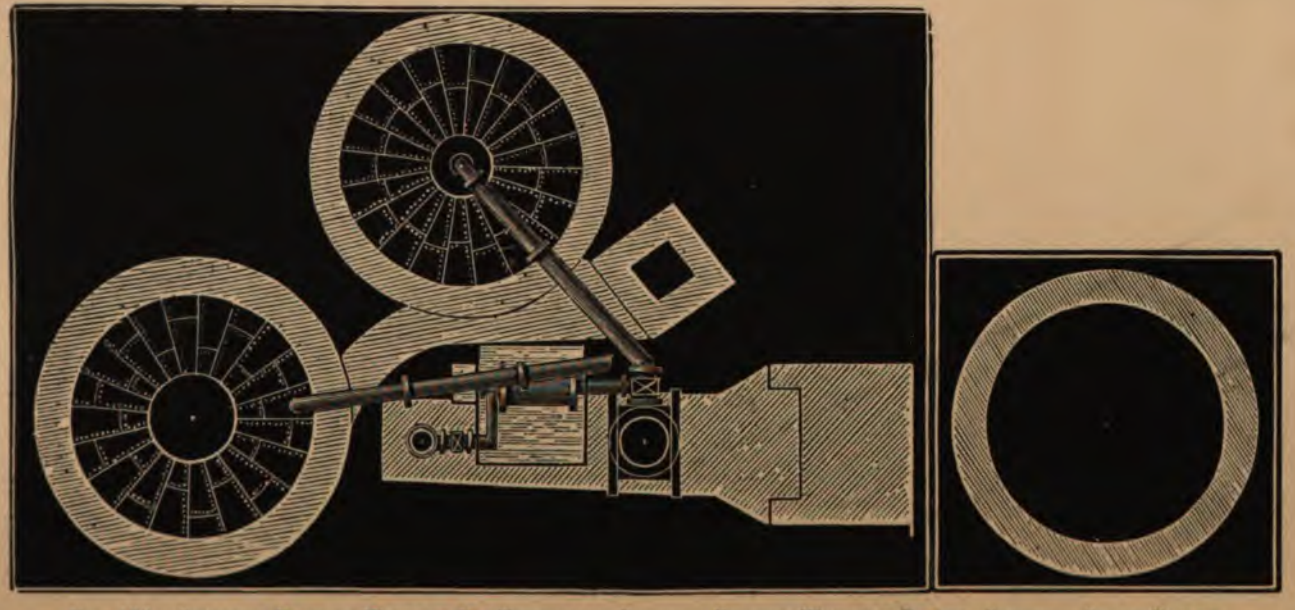


FIG. 136.—SHOWING PLAN OF WILLIAM PIT TEMPORARY PUMPING ENGINE, WORKING BOILER, CHIMNEY, SPARE BOILER, AND PIT SHAFT.

[*To face page* 181*b*.]



FIG. 137.—SHOWING END ELEVATION OF WILLIAM PIT TEMPORARY PUMPING ENGINE.

[*To face page* 181c.]

side of the piston of the other cylinder counteracts the pressure of the atmosphere on its upper side, and the power of the first cylinder causes that end of the regulator beam to descend, and moves the crank and rope barrel one-half of a revolution. The steam valve is then shut, and the exhaust valve opened, the jets of cold water continuing to flow into the pipes, the steam in the cylinders and pipes is condensed, so that the air acts by its pressure on both the cylinders, but one cylinder being double the power of the other cylinder overcomes its resistance and raises the basket by moving the crank and rope barrel the other half of the revolution. Again the exhaust valve is shut and the steam valve is opened, the atmosphere acts upon the piston, at the same time the steam acts on the under side of the piston of the cylinder. And so the motion is repeated.

It takes this engine twenty strokes, which is twenty revolutions of the rope barrel, to raise a basket (weight—rope and basket—1,700 lbs.) 95 fathoms, or the depth of William pit.

This the engine has performed in forty seconds, and its common rate of doing it is forty-five seconds, or about 12 ft. per second.

There would only be one rope attached to this engine, and it would be of hemp, and the total weight is given as 1,700 lb., which would mean that weight to start at a depth of 95 fathoms. Probably the respective weights would be about 500 lb. the rope and 1,200 lb. the basket and coals. The average load, consequently, would be 1,700 + 1,200 = 2,900 ÷ 2 = 1,450 lb. raised at an average speed of 570 ft. in forty-five seconds, being 760 ft. per minute, representing a useful horse-power of about 30. Verily we have made some progress as regards power of winding engines in these eighty years. A good winding engine in 1806 shows useful horse-power 30; many winding engines in 1883 can develope 1,000 horse-power.

William Pit Temporary Pumping Engine.—This is a single atmospheric engine, and figs. 135, 136, 137 show the following parts, namely:—

1. The cylinder, open-topped, 44 in. diameter, with a 7 ft. stroke.

2. The regulator beam.
3. The air-pump beam.
4. The boiler, 15 ft. diameter.
5. The condenser.
6. The air-pump, 18 in. diameter and 3½ ft. stroke.
7. The engine chimney, 32 ft. high.
8. The condensing cistern.
9. The blow-valve cistern.
10. The pipe from the pond to supply the boiler with water.
11. The steam pipe from the boiler to the cylinder.
12. The blow-valve.
13. The air-pump parallel motion.
14. The plug frame.
15. The wye.
16. The top set pumps.
17. The launder box and troughs.
18. The deadmen and hanks to hold down the cylinder.
19. The lever and weight for loading the safety valve.
20. The great engine pumps.
21. The present working pit.
22. The second ditto, after the temporary pumps are taken out.
23. A spare boiler.

When this engine is to be set forward the steam and exhaustion valves are opened, the steam from the boiler fills the cylinder (the piston being at the top of its stroke), the condenser, and air-pump, and expels the air out at the blow valve. The steam valve is shut, the injection valve opened, and the cold water from the cistern condenses the steam; the air then acts upon the piston of the cylinder, and forces it to the bottom of the cylinder. This part of the stroke lifts the water out at the top of the pumps.

The exhaustion valve is then shut, and the steam valve opened; the steam then enters under the piston of the cylinder and counteracts the pressure of the atmosphere, while the weights of the wye and wood rods in the pumps raise the inner end of the regulator beam and depress their own end. Again, the steam valve is shut and the exhaustion valve opened, the steam from under the piston of the cylinder rushes into the condenser and is condensed,

and the air again forces the piston to the bottom of the cylinder lifting more water out at the top of the pumps.

The cylinder being 44 in. diameter, and reckoning the pressure of the air at 10 lb. upon every square inch, will lift a column of water equal to 6 tons 15 cwt.; 6 tons 15 cwt. = 135 cwt. = 15,120 lb. A cylinder exposed to an effective pressure from the atmosphere of 10lb. per square inch will represent in a diameter of 44 in. = 1,520 square inch area, a power of 15,200 lb., allowing nothing at all for frictional resistances. Probably the effective power of this atmospheric pumping engine has been somewhat over-estimated, and a reasonable statement of its capabilities in practice would be to say that at a depth of 50 yards it would deal with a bucket about 14 or 15 in. diameter, and would raise per stroke about 50 gallons of water; and of course greater sizes and larger quantities for less depths, and smaller sizes and less quantities for greater depths.

Such is Mr. Longmere's matter, kindly placed at our disposal by Mr. Harden, and which comes in as a kind of *postscript* to our chapters on pumping machinery. The present writer hopes his readers will share some of the pleasure that has fallen to his lot in reproducing the illustrations and text of nearly a hundred years ago. May those who occupy our places a century hence think as kindly of us as we do of our ancient friends at Whitehaven.

CHAPTER XVIII.

MEMORANDA FOR MINING ENGINEERS.

Actual and Theoretic Efficiency of Coal—Duty of an Engine—Nominal Horse-power — Useful Horse-power — Indicated or Actual Horse-power—Table of Approximate Horse-power with Cylinders 6 in. to 60 in. diameter—Average Effective Pressure 30 lbs. and Average Piston Speed 250 feet per minute—What is Average Effective Pressure?—Rule to find Diameter of Winding Drum and Pressure of Steam, knowing the Load, the time of Winding, and Diameter of Cylinder—Different Kinds of Steam, Saturated, Wet and Superheated—Table of Saturated Steam, showing Absolute Pressure, Latent Heat, Sensible Heat, Boiling Point, and Volume compared with Water—Rule to find Quantity of Condensing Water required—Strength of Materials—Tenacities—Resistance to Compression—Strength to resist Twisting Strains—Transverse Strengths—Dead Load and Live Load—Conductivity of Metals—Temperature of Fusion—Specific Heat—Expansion produced by Heat—Moduli of Elasticity—Pressure from the Barometer, showing Height of Mercury Column in Inches, Pounds Pressure per Square Inch and per Square Foot—Fahrenheit's and Centigrade Thermometers—Pressure of Water Columns—Head, Velocity, and Quantity of Water from Pipes, showing Diameter of Pipe in Inches, Head required per 100 feet and Gallons delivered per minute—Delivery of Water in Pipes—To find the Quantity of Water in a Pipe—To find the Quantity of Water delivered by a Pump per minute—Falling Bodies—Weight of Pipes, &c.—Effect of Temperature upon Iron and Copper—Weight of a Boiler—Collapsing Pressure of Boiler Tubes—Weight of Cubic Inch of Wrought Iron and Cast Iron—Fixing the Number of Boilers required for the Generation of Steam—Determining the Minimum and Maximum Diameters of a Perfect Compensating Drum—Mechanical Ventilation—Work in Velocity of Air apart from Friction—Water Gauge calculated from Circumferential Velocity of Fan.

THE following rules and memoranda bearing upon Mining Engineering are, with few exceptions, not original—it must be a very long time since such memoranda could be

called original; but they have been carefully selected from the most reliable sources, and are given here in as plain and practical a shape as possible:—

Actual and Theoretic Efficiency of Coal.—A pound of average coal developes, with perfect combustion, 12,000 units of heat, which, multiplied by 772, the mechanical equivalent in units of work of one unit of heat equals 9,264,000 foot-pounds of work, representing barely a consumption of ¼ lb. of coal per indicated horse-power per hour. The very best engines of modern times, leaving out only a few exceptional cases, require not less than 2½ lb. of coal per horse-power per hour—showing a loss in some form or another of nine-tenths of the efficiency of the coal used for the generation of steam. The average colliery engine uses very much more than 2½ lb. of coal per horse-power per hour, consequently the loss of efficiency is very much greater.

Duty of an Engine.—For an engine working a short period during which we take diagrams we calculate the work in horse-power; but for a long period—especially for pumping engines—we reckon by a larger standard, and the term duty indicates the number of millions of pounds raised through the height of 1 ft. by the burning of a bushel of coal, which, being an indefinite quantity some years ago, varying from 84 to 94 lb., has now been fixed at 112. For engines other than pumping, we estimate the performance by ascertaining the number of pounds of coal burnt per hour for each horse-power at which the engine is working.

Horse-Power.

Nominal Horse-Power is simply an expression of dimension, which in the early days when all steam engines worked with about the same pressure and at about the same speed had some real intelligible meaning attached to it; but in these days of pressures varying from several pounds to several hundreds, and speeds varying from 50 ft. per minute to 1,000 ft. per minute is simply misleading. Some authorities allow 11 square inches of piston area for one nominal horse-power in a

high-pressure engine, and 22 square inches piston area per nominal horse-power in a low pressure engine.

Useful Horse-Power represents the real work done without allowing for resistances, such as friction of machinery, &c. For a winding engine the useful work would be the pounds of coal raised through a given height in feet per minute, and these multiplied together and divided by 33,000 would give the useful horse-power. In a pumping engine we simply take the weight of water instead of weight of coals.

Indicated or Actual Horse-Power is the power actually being exerted by the engine, and includes resistances, such as resistances of machinery, &c., as well as useful work. The indicated horse-power is found by multiplying the average effective pressure per square inch upon the piston by the area of the piston in square inches, and multiplied again by the speed of the piston in feet per minute, and divided by 33,000. The average effective pressure is not the pressure of steam in the boiler or the engine-house, or even in the cylinder; it is the difference between the pressure urging the piston forward and the pressure of exhaust keeping it back. It will have been observed in these articles that, knowing the actual load, whether for winding, pumping, or hauling, one-half has always been added for resistances. This may seem extravagant, but a golden rule in all mining machinery is to have a good margin of power.

Actual Horse-power of Engines.—Assuming an effective pressure of 30 lb., and a piston speed of 250 ft. per minute:—

Diameter of cylinder.	Actual horse-power.	Diameter of cylinder.	Actual horse-power.
6 inches	6	24 inches	103
7 „	8	25 „	111
8 „	11	26 „	120
9 „	14	27 „	130
10 „	18	28 „	140
11 „	22	29 „	150
12 „	26	30 „	160
13 „	30	32 „	183
14 „	35	34 „	207
15 „	40	36 „	231
16 „	46	38 „	258
17 „	51	40 „	285
18 „	58	42 „	312
19 „	64	45 „	361
20 „	71	48 „	411
21 „	78	50 „	446
22 „	86	54 „	520
23 „	94	60 „	642

In the foregoing table allowance has not been made for the piston rod; but, especially in the larger sizes, and if no back piston rods are used, this will not materially affect the results. And decimals have not been included. What is intended is to give a fairly approximate table of horse-power for the sizes of engines most in use. Having such a table for 30 lb. pressure and 250 ft. piston speed, it is not difficult to determine the horse-power for any other pressure and any other speed. We have assumed an average piston speed of 250 ft. per minute, because that is a fair speed in engines working continuously for any length of time.

In winding-engines we have cases where the average piston speed will be from 400 to 500 ft. per minute; but there is a great difference between running an engine for thirty or forty seconds, as with a winding engine, and twelve or twenty-four hours, as with a pumping engine, and several months as with a fan engine. What we term a fair average speed is that at which the engine can work without distress for a considerable period continuously; and we have assumed an average effective pressure of 30 lb., because even at the generality of modern collieries this will be found about correct.

Rule to find Diameter of Winding Drum and Pressure of Steam.—Having the load to be raised, the time of a winding, the length of stroke and the diameter of cylinder, to determine the pressure of steam and the diameter of the winding drum. The following rule may be found to apply:—Assume an average piston speed in winding engines at 400 ft. per minute; multiply this by the number of seconds which a winding occupies, and divide by 60. This gives the distance in feet which the piston travels each winding, and, divided by twice the length of stroke, gives the number of revolutions in each winding. The depth of the pit in feet divided by this number of revolutions gives the circumference of the drum. Multiply the circumference of the drum by the load in pounds, and call this result No. 1; multiply the area of the piston in square inches by twice the length of the stroke in feet, and call this result No. 2. Divide the first result by the second result, and we have the theoretic pressure of steam, to which add one-half for resistances.

Take, as an actual example, a single engine with cylinder 30 in. diameter and stroke 5 ft., with properly balanced arrangements, such that only the actual weight of coals—2 tons—has to be dealt with, the depth of the pit being 1,200 ft., and the period of a winding 40 sec.; then 400, the average speed of the piston in feet per minute, × 40 and ÷ 60 = 266 ft. ÷ 10 = 26·6, or, say, 26½ revolutions to a winding. The drum makes an equal number of revolutions with the engine, and 1,200 ft. ÷ 26½ = 45 ft. 3 in., the circumference of the drum, which, ÷ 3·1416, will equal 14 ft. 5 in., the diameter of the drum.

We have now the load, 2 tons = 4,480 lb. at the circumference of the drum, which is 45 ft. 3 in., and we have steam acting upon a piston 30 in. diameter = 706 square-inch area; then 4,480 × 45¼ ft. = 202,720, and 706 × 10 ft. = 7,060, and 202,720 ÷ 7,060 = 28¾ lb., the average theoretic effective pressure of steam, adding one-half for resistances, 28¾ + 14¼ = 43 lb. pressure of steam average effective upon the piston, and a drum 14 ft. 5 in. diameter for an engine with cylinder 30 in. diameter and stroke 5 ft., and perfectly balanced arrangements, to raise 2 tons of coals 400 yards in forty seconds.

Different Kinds of Steam.

Steam may be termed saturated, or wet, or superheated. Saturated steam is true steam vapour formed in good steam boilers. Frequently, and especially in boilers that prime, or where the steam is cooled after its formation, it becomes mixed with more or less water in the form of spray, and then we get wet steam. Superheated steam is formed by imparting more heat to saturated steam, the usual method being to pass it through a superheater formed of tubes or plates heated on the other side by the products of combustion on their way to the chimney. Superheating tends to economy, but the extent to which it can be carried is limited to a few degrees, owing to the injurious chemical action upon the metal of the cylinder and the excessive friction caused by the high temperature.

Saturated Steam.

Absolute pressure in pounds.		Latent heat.	Latent and sensible heat.	Temperature Fahr., of boiling point.	Volume	
Per sq. inch.	Per sq. foot.				Compared with water.	Cubic ft. per lb.
·0	·0	...	...	...	...	...
5·0	720	1000·95	1163	162	4559	73·05
10·0	1440	979·22	1173	193	2363	37·87
14·7	2116·8	966·00	1178	212	1644	26·36
20·0	2880	954·79	1183	228	1231	19·70
25·0	3600	946·00	1187	240	998	15·97
30·0	4320	938·87	1190	250	841	13·46
35·0	5040	933·00	1193	259	729	11·66
40·0	5760	927·00	1195·5	267	640	10·28
45·0	6480	922·00	1198	274	576	9·22
50·0	7200	917·00	1199·5	281	522	8·35
55·0	7920	913·00	1201	287	477	7·64
60·0	8640	909·00	1203	292	440	7·05
65·0	9360	905·00	1205	298	408	6·55
70·0	10080	901·50	1206	302	381	6·10
75·0	10800	898·00	1208	307	357	5·72
80·0	11520	895·00	1209	312	337	5·39
85·0	12140	892·00	1210	316	317	5·10
90·0	12960	889·00	1211·5	320	301	4·83
95·0	13680	886·00	1213	324	286	4·60
100·0	14400	883·62	1214	327	273	4·37

Condensing Water.—Let W = weight of steam to be condensed, T = its temperature, l = its latent heat, W^1 = weight of injection water required, t = its temperature, t^1 = temperature of the mixture. Then $W^1 = \frac{(T + l - t^1)\,W}{t^1 - t}$, the latent heat of steam varying from 966 at atmospheric pressure to 939 at 15 lb., and 920 at 30 lb. above the atmosphere. Put into words, it reads that temperature of steam + latent heat − temperature of mixture. Result × weight of steam to be condensed and ÷ temperature of mixture − temperature of injection water will give the weight of injection water required.

Strength of Materials.—The results of the very numerous experiments made on materials by individuals and institutes vary to such an extent that all tables must be more or less approximate only. In recording the various figures below, where different authorities have agreed, there has been no difficulty in accepting their united decision; where they disagree, an average has been taken. The materials are assumed of high quality, and the various strengths are ultimate, by which we mean the amount of stress which will produce fracture. Proof strength is the stress required to produce the greatest strain in some specified way consistent with safety. A stress exceeding the proof strength, though it does not produce immediate fracture, will produce it by long application or by frequent repetition. The working stress is always made considerably less than the proof strength in a certain ratio determined by experience.

Tenacities.

Steel	115,000 lb.	per square inch.
Wrought iron ...	60,000 ,,	,, ,,
Cast iron	16,000 ,,	,, ,,
Copper wire ...	60,000 ,,	,, ,,
Cast brass... ...	18,000 ,,	,, ,,
English oak ...	17,500 ,,	,, ,,
Elm	13,500 ,,	,, ,,
Riga fir	12,000 ,,	,, ,,
Larch	10,000 ,,	,, ,,

Resistance to Compression.

*Steel	200,000	lb. per square inch.
Cast iron	110,000	„ „ „
Wrought iron ...	36,000	„ „ „
Cast brass... ...	10,000	„ „ „
Granite	8,000	„ „ „
Sandstone... ...	4,000	„ „ „
Limestone... ...	4,000	„ „ „
English oak ...	9,500	„ „ „
Larch	5,500	„ „ „
Riga fir	6,000	„ „ „
Elm	10,000	„ „ „

Strength to Resist Twisting Strains calculated upon bars 1 in. diameter, and strain applied to the extremity of a lever 1 ft. long :—

Cast steel,	from ...	1,150 to 1,900 pounds.
Wrought iron	„ ...	700 to 1,000 „
Cast iron	„ ...	650 to 750 „
Wrought copper	„ ...	400 to 450 „

And the torsional strength increases as the cube of the diameter, and decreases as the length of the lever increases, to which the strain is applied.

Transverse Strengths calculated upon bars 1 in. square resting upon two supports, 1 ft. between the supports, and load concentrated in the middle :—

Teak	820 pounds.
English oak	557 „
Ash	675 „
Beech	518 „
Elm	337 „
Pitch pine	544 „
Red pine	447 „
Riga fir	369 „

---

* Rivington says :—The crushing strength of steel varies greatly, according to the quality of the steel and the hardness to which it has been tempered. Some cylinders of cast steel of a height = 2½ diameters, cut from the same bar, were crushed under the weight given below :—

Not hardened	89	tons per square inch.
Hardened, low temper ...	158	„ „ „
Hardened, high temper ...	166	„ „ „

Larch	284 pounds.
Mahogany	531 „
Cast iron	2,500 „
Wrought iron	3,500 „
Steel	6,500 „

These strengths increase as the breadth increases, and as the square of the depth, and decrease as the distance between the supports increases. These strengths refer to beams simply resting upon supports at each end. When securely fixed at both ends the strength is much increased; some authorities put the increased strength at 50 per cent., and others 100. The value of this increase is somewhat uncertain, and the safe method is to calculate as if the beam simply rested upon its supports. The strength over and above this is gain. The transverse strength of a cylindrical beam will increase as the cube of the diameter. A dead load is that which is very gradually applied, and which remains steady. The weight of any structure itself is a dead load. A live load is that which is applied suddenly or is accompanied by shocks or vibration. A fast train coming on to a bridge, or a sudden gust of wind upon a wall cause live loads. The shocks and jerks upon winding and hauling ropes, and upon cage chains in starting may be considered as live loads. Practically, a live load produces in most cases twice the stress and strain which a dead load of the same weight would produce. A winding rope and cage chain may be considered as having a strain exerted upon them at starting equal to double the weight they are lifting.

Conductivity of Metals.

	For Heat.	For Electricity.
Silver	100	100
Copper	74	73
Gold	53	59
Brass	24	22
Zinc	20	—
Tin	15	23
Steel	12	13
Iron	12	13

	For Heat.	For Electricity.
Lead	9 ...	11
Platinum	8 ...	10
German silver	6 ...	6
Bismuth	2 ...	2

As silver has the highest conductivity of any metal, it is taken as the standard by which to exhibit the comparative values of all others. Dr. Alder Wright, in his article on "Iron" in Volume XIII., new edition, of *Encyclopædia Britannica*, says electrical conductivity and power of conducting heat are always approximately in the same ratio. Professor Tyndall, in his *Heat a Mode of Motion*, remarks that, as regards their powers of conducting heat, metals differ very widely from each other, as, for example, the conductive power of silver is 100, whilst that of German silver is only 6. This striking difference may be illustrated in a very simple way—by plunging two spoons, one of German silver and the other of pure silver, into the same vessel of hot water. After a little time the free end of the silver spoon has become much hotter than the inferior article, and if bits of phosphorus were placed on the ends of the spoons, that on the silver will fuse and burn, while the heat transmitted through the other spoon never reaches an intensity sufficient to ignite the phosphorus. The above table, showing copper to have a conductivity 74 and iron only 12, affords a very simple and excellent explanation why locomotive fire-boxes answer so much better made of the former material.

Temperature of Fusion.

	Centigrade.	Fahrenheit.
Mercury	— ...	—40
Ice	0 ...	+32
Phosphorus ...	44 ...	111
Sulphur	110 ...	230
Tin	230 ...	446
Bismuth	265 ...	509
Lead	320 ...	608
Zinc	360 ...	680
Antimony	432 ...	810

	Centigrade.	Fahrenheit.
Bronze	900	1,652
Silver	1,000	1,832
Copper	1,150	2,102
Gold	1,235	2,319
Cast iron	1,250	2,102
Wrought iron	1,500	2,822
Steel	1,350	2,460
Platinum	2,000	3,632
Brass	1,029	1,968

It is not easy to fix exactly the melting point of iron. Pouillet gives the melting point when in a state of high purity as between 1,500 degs. and 1,600 degs. Cent.; Silvester gives it as 2,100 degs. Cent., Deville at 1,900 to 2,000 degs. Cent. The presence of minute quantities of carbon sensibly lowers the fusing point; whilst 1 per cent. of carbon furnishes a steel melting at several hundred degrees lower than pure iron. Cast iron containing some 3 per cent. of carbon will melt at 1,500 degs. Cent., and will be made still more fusible by the presence of small quantities of sulphur and silicon.

Specific Heat.—The specific heat of any body is its capacity for heat—that is, the quantity of heat required to raise a unit of its weight through one degree of temperature—and is sometimes termed heat capacity. Pure water at its greatest density, 39·1 Fahr., has been adopted as the unit of specific heat.

Water	1·0	Brass	0·094
Antimony	0·05	Gold	0·032
Silver	0·056	Platinum	0·032
Bismuth	0·030	Lead	0·031
Copper	0·092	Zinc	0·095
Tin	0·056	Mercury	0·033
Iron	0·1138		

One pound avoirdupois weight of water raised 1 deg. Fahr. represents one British heat unit, and if expressed by the Centigrade scale would be equal to 0·55. The mechanical equivalent of heat is 772 foot-pounds for one British heat unit; for 1 deg. Centigrade it is 1389·6 foot-pounds. A French heat unit will equal 3·9683 British heat units.

Expansion produced by Heat.

Temperature raised 1 deg. Fahr.

In length—	Glass	0·00000431
	Platinum	0·00000476
	Cast iron	0·00000617
	Wrought iron	0·00000642
	Steel	0·00000636
	Brass	0·00001052
	Lead	0·00001592
	Zinc	0·000016333
	Tin	0·000012070
	Copper	0·00000944
In bulk—	Mercury	0·000000550
	Air and all permanent gases ...	0·000011300
	Water	0·000001500

Wrought-iron rails on a railway ten miles long, having their temperature raised from 32 degs. below freezing, will, if raised in temperature to 88 degs. Fahr., lengthen ten yards. A cubic foot of lead at 60 degs. Fahr. will decrease in volume at 0 degs. Fahr. to 0·997134 cubic feet, and increase in volume to 1·00133728 cubic feet at 92 degs. Fahr. At somewhat elevated temperatures the rate of expansion in iron is higher, the mean expansion between 0 degs. and 100 degs. Cent. is to that between 0 degs. and 300 degs. Cent. nearly in the ratio of 4 to 5. The force exerted during expansion is very great, being equal to that requisite to produce an elongation of the bar to the extent through which its length increases by heat. Thus, according to Barlow, a weight of one ton suspended to an iron bar a square inch in section will extend its length by 0·0001 times the original length, so that 1 in. length will become 1·0001 in. This increase in length would be brought about by a rise in temperature of about 9 degs. Cent.; hence, for an increase of 36 degs. Cent., or less than the average difference between a cold and warm day in winter and summer respectively—that is to say, between a day in December and one in June—a girder of iron of twenty square inches in section would exert a thrusting strain upon two walls built firmly up to its ends when coldest equal to about

80 tons for each inch of its length, were it not that the pressure is more or less relieved by the giving of the walls. In consequence, it is indispensable to allow a space for expansion in all constructions in which iron is employed, as, for example, ordinary buildings, railways, and furnaces braced together with tie-rods.

With large masses of ironwork exposed to the weather very great strains may be produced through unequal expansion in differently heated parts, as, for instance, in the portions exposed to sunshine and in the shade respectively. It has been calculated that half-an-hour's sunshine produces more effect in the way of developing strain on the tubes of the Britannia Bridge over the Menai Straits than the heaviest rolling loads or the most violent storms.

Moduli of Elasticity.—The modulus of elasticity is that strain per square inch of the section of a bar which would double its length if its elasticity continued perfect; but, of course, no solid substance has limits of elasticity any way approaching this in extent. Still, having these moduli, we can ascertain how far a substance will stretch under a certain strain when we know the amount of strain, the length and section of the bar. For example, a wrought-iron bar three square inches in section and fifty feet long is exposed to a strain of 6 tons; how much will it elongate? The length, 50 ft.; the section, 3 square inches; the strain, 13,440 lbs.; the modulus of elasticity, 28,450,000 lbs. per square inch. Then the length in feet, 50 × strain in pounds, 13,440 ÷ (square inches of section, 3 × modulus of elasticity, 28,450,000) shows that the bar will stretch between one-tenth and one-eleventh of an inch.

	Lbs. per sq. in.		Lbs. per sq. in.
Cast steel	31,000,000	Teak	2,400,000
Wrought iron ...	28,450,000	Red pine	1,840,000
Cast iron	19,550,000	English oak	1,450,000
Drawn copper.....	17,870,000	Beech	1,350,000
Drawn brass	15,580,000	Riga pine	1,330,000
Flint glass	8,325,000	Elm	700,000

Height of mercury column in inches.	Pounds pressure per square inch.	Pounds pressure per square foot.
27	13·25	1,908
27¼	13·37	1,925
27½	13·49	1,943
27¾	13·61	1,961
28	13·74	1,979
28¼	13·86	1,996
28½	13·98	2,014
28¾	14·11	2,032
29	14·23	2,049
29¼	14·35	2,067
29½	14·47	2,085
29¾	14·60	2,102
30	14·72	2,120
30¼	14·84	2,137
30½	14·96	2,155
30¾	15·09	2,173
31	15·21	2,190

2·035 in. of mercury column and 27·68 in. of water column each represents 1 lb. pressure per square inch, or very nearly 1 in. of mercury column represents ½ lb. pressure per square inch, and each atmosphere of 14·706 lb. per square inch = 33·9 ft. of water column.

Fahrenheit's and Centigrade Thermometers.—There is no fixed rule as to which scale of temperatures shall be used, and it is well to have a knowledge of both. The boiling point of water under mean atmospheric pressure of 14·7 per square inch is 212 degs. Fahr. and 100 degs. Cent.; the melting point of ice under atmospheric pressure is 32 degs. Fahr. and 0 deg. Cent. The supposed absolute zero of temperature is − 461·2 degs. Fahr., and − 274 degs. Cent. To convert any number of degrees Fahr. into degrees Cent., or *vice versa* :—Degs. Fahr. $\times \frac{5}{9}$ = degs. Cent.; degs. Cent. $\times \frac{9}{5}$ = degs. Fahr. To convert temperatures Fahr. into temperatures Cent., or *vice versa* :—Temperature Fahr. − 32 $\times \frac{5}{9}$ = temperature Cent.; temperature Cent. $\times \frac{9}{5}$ + 32 = temperature Fahr.

Pressure of Water Columns.—To find the pressure per square inch of a column of water:—To work this out exactly we take 1 cubic foot = 1,728 cubic inches of water as weighing 62·4 lb., so that a column 1,728 in. = 144 ft. high exerts a pressure of 62·4 lb. per square inch; and having the column in feet we multiply by 62·4 and divide by 144, as, for example, a column 200 ft. high; then 600 × 62·4 = 37440·0 ÷ 144 = 660 lb. pressure per square inch. A somewhat readier rule, which has been adopted in these chapters, is to assume a column of water 34 ft. high exerting a pressure of 15 lb. per square inch. Take the same column in this case:—600 × 15 = 9,000 ÷ 34 = 264 lb., which is more readily worked, and quite near enough for practical purposes. Another rule is: multiply the height in feet by ·434. According to this, 600 × ·434 = 260·400 lb.; and to obtain the pressure upon a circular inch we multiply the height in feet by ·341. An exceedingly ready rule is to take half the height in feet, which, for a column of 600 ft., would be an error of 40 lb. per square inch, but on the right side; and for comparatively small columns up to, say, 50, or even 100 ft., the error is not important.

To find the pressure of a column of water in pounds:—If the base be circular, square the diameter in inches, and multiply by ·34, and then by the height in feet. If the base is square, multiply the square of the side in inches by ·434, and again by the height in feet.

The foregoing enable us to determine pressures when the height of the column is known. To determine heights when we know pressures would be simply to reverse the process.

Head, Velocity, and Quantity of Water from Pipes.—The following table gives the head of water required to produce a velocity of 200 ft. per minute through pipes varying in diameter from 1 in. to 24 in., and also the gallons of water delivered per minute:—

Diameter of pipe in inches.	Head required per 100 feet.	Gallons delivered per minute.
1	5·33	6·796
2	2·67	27·184
3	1·78	61·227
4	1·33	108·738
5	1·07	169·966
6	0·89	244·786
7	0·76	331·198
8	0·67	435·203
9	0·59	550·924
10	0·53	680·113
11	0·49	823·020
12	0·45	979·518
13	0·41	1149·110
14	0·38	1333·043
15	0·36	1530·069
16	0·33	1740·812
17	0·31	1965·895
18	0·30	2203·449
20	0·27	2720·320
22	0·24	3292·808
24	0·22	3917·450

Delivery of Water in Pipes.—Let D = diameter of pipe in inches, H = head of water in feet, L = length of pipe in feet, W = cubic feet of water discharged per minute. Then (1) $W = 4{\cdot}72 \sqrt{\frac{D^5 H}{L}}$. That is, raise the diameter in inches to the 5th power, and multiply by the head of water in feet, divide this result by the length of the pipe in feet, take the square root of this product, and multiplying by 4·72 will give cubic feet of water discharged per minute. And (2) $D = 538 \sqrt[5]{\frac{L W^2}{H}}$. That is, multiply the length of the pipe in feet by the cubic feet of water discharged per minute squared; divide this result by the head of water in feet, take the fifth root of the product, and finally multiply by 538, which gives the diameter of the pipe in inches.

To find the Quantity of Water in a Pipe.—Take the quare of the diameter in inches, and strike off one figure to the right; this gives number of gallons in one yard

long. Take a pipe 12 inches diameter—12 × 12 = 144—and striking off one figure to the right shows 14·4 gallons in one yard long of 12 in. piping.

To find the Quantity of Water in Gallons delivered by a Pump per Minute.—Square the diameter in inches, and multiply by ·034, and again by the speed in feet per minute. A cylinder 1 in. diameter and 1 ft. long contains ·034 of a gallon. A pump 5 in. diameter double-acting makes 200 working feet per minute: what quantity of water in gallons will it deliver in one minute? 5 × 5 = 25 × 0·034 = 0·850 × 200 = 175 gallons per minute.

Falling Bodies.—Reckoning gravitation a constant quantity 32·2—(1.) The height in feet or vertical distance through which a body will fall in a given time is, number of seconds squared × 16·1. (2.) The velocity in feet per second acquired at the end of a given time is, number of seconds × 32·2. (3.) The velocity in feet per second due to a given height of fall is, square root of height × 8·025. (4.) The height of fall due to a given velocity in feet per second is, square of velocity ÷ 64·4.

Weight of Pipes, &c.—Let D = outside diameter in inches; d = inside diameter in inches; W = weight of a lineal foot in pounds. Then $W = K (D^2 - d^2)$ that is, weight of one foot only will be, outside diameter in inches squared, minus inside diameter in inches squared, and the difference multiplied by the co-efficient, K, which is taken as follows:—Cast iron, 2·45; wrought iron, 2·64; brass, 2·82; copper, 3·03; lead, 3·86. Another rule for weight of cast-iron pipes:—The area of a circle in inches multiplied by the length in inches, and by ·263 = the weight in pounds avoirdupois of cast iron. To get the weight of the pipe it is only necessary to ascertain the weight of the external and internal diameters and subtract the latter from the former.

To find the weight of a sphere of cast iron, cube the diameter in inches, and divide by 7·27. The result is the weight in pounds.

The strength of boilers of iron plates becomes greater as the temperature increases, up to about 400 degs.; beyond that temperature it becomes weaker.

Copper decreases in strength from 56 degs. upwards.

The weight of a boiler may be approximately ascertained by reckoning 6 lb. for each eighth of an inch in thickness for each superficial foot. This makes needful allowance for rivets and lap of joints.

The collapsing pressure of a boiler flue in pounds may be determined also approximately by multiplying the thickness of the plates in inches by 2·19, dividing this result by the length of the tube in feet, and again by the diameter of the tube in inches, and multiply the whole product by 806,300.

A cubic inch of wrought iron will weigh 0·28lb., and the cubic inches in a body divided by 8,000, 400, 100 and 3·5 respectively will respectively give the weight in tons, cwts., qrs., and pounds.

A cubic inch of cast iron will weigh 0·26 lb., and having the number of cubic inches, the weight in tons, cwts., qrs., and pounds may be obtained in the same way by dividing by 8,640, 432, 108, and 3·85.

Fixing the Number of Boilers required for the Generation of Steam.—It can be shown by methods laid down in previous chapters that having such an example as the following:—Output, 1,000 tons in eight hours; one minute for winding; half-minute for banking; depth, 600 yards, and steam pressure at the boilers, 60 lb.—that the winding machinery would come out: a pair of horizontal winding engines, with cylinders 32 in. diameter and 36 in. stroke, and winding drum 17 ft. 3 in. diameter, and the load of coals each winding 62½ cwt. This is supposing a balance rope in use under the cages; if not, without altering other dimensions, the cylinders would become 42 in. instead of 32.

To determine the number of boilers necessary, on the understanding that Lancashire boilers—each about 28 ft. long and 7 ft. diameter—are intended, we assume each boiler capable of generating steam for 200 horse-power, with a consumption of fair average coals each boiler of 1 ton in three hours, and proceed as follows:—The engines are taken as having an average piston speed of 400 ft. per minute, and the average effective pressure upon the piston ⅔ that at the boilers—namely, ⅔ of 60 = 40 lb. Then 32 in. diameter = 804 square inches area × 40 = 32,160 × 400

= 12,864,000 ÷ 33,000 = 390 × 2, being two engines = 780 horse-power, showing that four boilers will be needed.

Without the balance rope, and having a cylindrical drum, the cylinder will be 42 in. Then 42 in. diameter = 1,385 square inch area × 40 = 55,400 × 400 = 22,160,000 ÷ 33,000 = 670 × 2, being two engines = 1,340 horse-power, showing that seven boilers will be needed, a striking evidence of the advantage of balanced over unbalanced loads in winding. We have taken in each case the size of engines required to start the load. It may be said that the power of each boiler is over-estimated, and that if 200 horse-power can be generated at 60 lb. pressure we shall not realise 200 horse-power when only two-thirds of the boiler pressure is effective. That is so; but to balance this a winding engine is not a continuous working engine, and may be taken, as in our case it is exactly, working two-thirds of its time.

Determining the Minimum and Maximum Diameter of a Perfect Compensating Drum.—In the preceding example we have a load of coals each winding 62½ cwt., and assuming a cage to weigh 5,000 lb. and empty tubs 2,000 lb., we should require a rope of such strength that its weight for 600 yards deep would be about 5,400 lb. We have dealt with cylindrical drums with and without the balance rope, but there are other methods of introducing what we term compensation, by using winding drums whose diameters vary so as to make the load upon the engine uniform all through the winding. The problem in such a case is having all the needful data to fix these diameters. It can be laid down and solved mathematically with ease by mathematicians; but the readers of these chapters, and certainly those for whom they are written, are far from being mathematicians, and the idea now is to show how this may be, with a little trouble, accomplished by the ordinary rules of arithmetic. What complicates the problem is that not merely is one winding rope coiling upon the drum and making its load less, but the opposite rope is coiling off the drum and making its load greater. The data are as follow:—Coals, 7,000 lb.; cage, 5,000 lb.; tubs, 2,000lb., and rope, 5,400 lb. We endeavour to show in something

like diagram form the corresponding positions of loaded and empty cages and their respective loads.

A.	B.
Empty cage at bottom.	Loaded cage at top.
Lbs.	Lbs.
5,000, cage	5,000, cage
2,000, tubs	2,000, tubs
5,400, rope	7,000, coals
12,400, total.	14,000, total.
C.	**D.**
Empty cage at top.	Loaded cage at bottom.
Lbs.	Lbs.
5,000, cage	5,000, cage
2,000, tubs	2,000, tubs
	7,000, coals
	5,400, rope
7,000, total.	19,400, total.

To make the load uniform the difference between the total load B × its diameter, and total load A × its diameter must exactly equal the difference between total load D × its diameter, and total load C × its diameter. One diameter, either the maximum or minimum, is fixed, and the other ascertained by trial. In the above case the maximum diameter was fixed at 20 ft., and the minimum diameter comes out as nearly as possible 13·2 ft.

A, 12,400 × 13·2 = 163,680. B, 14,000 × 20 = 280,000.
280,000 − 163,680 = 116,320.
C, 7,000 × 20 = 140,000. D, 19,400 × 13·2 = 256,080.
256,080 − 140,000 = 116,080.

In practice that would be a better compensating winding drum than one calculated upon theoretic principles, in which the diameter to commence the journey was less than the theoretic diameter, so as to give the engines additional power to overcome the inertia and get up speed; and the diameter to finish the winding should be greater than the theoretic diameter, and thus assist in overcoming the momentum of the machinery and stop the engines.

Mechanical Ventilation.—Work in Velocity of Air apart from Friction.—It was explained in Vol. I., in the section on Mechanical Ventilation, that the ordinary method of comparing the usual effect of fans—viz., to take the horse-power of the engine from the indicator diagrams of the steam cylinder, and the horse-power of the fan by multiplying the cubic feet of air per minute by the inches of water-gauge, and also by 5·2, and dividing by 33,000—was not absolutely accurate, because no allowance was made for the friction of the engine and means of connection between engine and fan, and all this was work included in the horse-power of the diagrams, but was work which, being used in another way, never reached the fan at all. It may be interesting here to show the actual work of ventilation, which is represented in the velocity at which the air is moving, apart from all resistances. Suppose, for example, 200,000 cubic feet of air per minute pass up an upcast shaft 12 ft. diameter, or along a drift equal to that in area, namely, = 113 square feet. The velocity of the air is 200,000 ÷ 113 = 1,770 ft. per minute, or very nearly 30 ft. per second. A body travelling at the rate of 30 ft. per second represents so much actual work, apart from resistances that have to be overcome, and that work is the height a body must fall to attain that velocity. To ascertain this height we square the velocity in feet per second and divide by twice the force of gravitation; 30 × 30 = 900 ÷ 64·4 =, say, 14 ft., which means that air travelling at a velocity of 30 ft. per second possesses, by reason of that velocity, power or work equal to raising itself to a height of 14 ft. The quantity of air is 200,000 cubic feet, and to find the horse-power we multiply the weight of this air in pounds per minute by 14 ft., and divide by 33,000. We may assume a cubic foot of water 62½ lb. and water 800 times heavier than air; then 200,000 × 62½ = 12,400,000 ÷ 800 = 15,500 × 14 = 217,000 ÷ 33,000 = nearly 7 horse-power in the velocity of the air, which is expended upon that velocity apart from work done in overcoming resistances. And if friction did not exist, this 7 horse-power would be the work needed to pass 200,000 cubic feet of air per minute at a velocity of 30 feet per second.

Water-gauge calculated from Circumferential Velocity of Fan.—Theoretically, and resistances apart, a fan should discharge a quantity of air at a velocity equal to the circumferential velocity and in quantity equal to circumferential area; but the resistances in the mine, and the shafts in the mine, and the shafts, and the fan itself prevent this. The water-gauge, however, should be dependent on the velocity of the fan; and that fan which with a given circumferential velocity, gives the highest water-gauge is, on the face of it, the best fan, because water-gauge being produced, quantity of air depends on friction in the mine. The water gauge might be calculated from the velocity of the fan as follows. But, first, what do we mean by water-gauge? We say 1 in. of water-gauge represents a pressure of 5·2 lb. per square foot, and as water may be taken as about 800 times heavier than air, then 800 in. ÷ 12 = 67 ft. nearly is the column of air equal to 1 in. of water-gauge. And such a column may act by direct pressure or by a velocity of air representing stored up work equal to a height of 67 ft., and we want to know what that velocity should be: 67 × 64·4 × 4,314, the square root of which is 66 ft. per second, the theoretic circumferential velocity of a fan to produce a water-gauge of 1 in. The water-gauge will be in proportion to the square of the velocity.

But if the air could not absolutely get into the fan, a certain velocity of the fan would probably produce a higher water-gauge. And if the air was not getting out of the fan, a certain velocity would give a less water-gauge, everything evidently depending upon a fair entrance to and exit from the fan. Still, we may say here that for water-gauges of 1, 2, and 3 inches, the theoretic circumferential velocities of a fan are about 66, 93, and 114 ft. per second = 3,960, 5,580, and 6,840 ft. per minute, equal respectively 42, 62, and 72½ revolutions per minute of a 30 ft. fan.

CHAPTER XIX.

HAULAGE.—INTRODUCTORY.

Importance of Hauling Machinery at Modern Collieries—Mr. Greenwell's Treatise on Mine Engineering—Hauling Arrangements in Early Times—The Basket on the Back—The Wheelbarrow—The Sledge, or Sled—Corves and Rolleys—Coal Tubs—Dr. Le Neve Foster in the *Encyclopædia Britannica*—Carriage of Blocks in the State Mines of the Ardennes—Iron Ore in Wooden Trays in the Forest of Dean—The German Hund—Cast-iron Tram Plates—Iron and Steel Rails—Cost of Haulage of Coals a Century ago compared with Modern Times—The Tail Rope Committee of the North of England Institute—W. Cochrane—G. B. Forster—John Daglish—Lindsay Wood—R. F. Matthews—Belgian Engineers—MM. Briart and Weiler—The Mariemont Collieries—Report on Haulage by Emerson Bainbridge—Lectures on Mining by M. Callon, French Inspector-General of Mines—Translation by W. Galloway and Dr. Le Neve Foster—Different Systems of Haulage in Different Districts—General Principles of all Hauling Arrangements—Machinery should always be used in preference to Horse or Manual Labour—Haulage Arrangements should communicate between Working Places and Pit Bottom—Machinery should have Power in Excess of Work—Haulage Power of Various Kinds—Water applied to Turbines and Hydraulic Engines—Electricity a Possible Power in the Future—Methods of Transmitting Power now most General—Steam in Engines placed Above Ground—Steam generated Above Ground working Engines placed Underground—Steam generated Underground and driving Engines there—Compressed Air—Arrangements when Roads have Falling Gradient to Pit Bottom—Systems of Haulage—Direct Haulage—Tail Rope Haulage—Endless Rope under the Tubs—Endless Rope over the Tubs—Endless Chain.

Amongst the mechanical operations of a mine haulage must necessarily in modern times occupy a foremost position. In the early days, when pits were sunk to work only a small area—when, as in Staffordshire at the commencement of this century, a winding engine would be placed in some central position so as to be able, when one

pit was exhausted at one point to sink another and connect it to the same engine, and so on, one engine probably having dealt in a comparatively short time with half-a-dozen shafts—the haulage arrangements were a matter of no importance, because the quantity was small, the distance scarcely anything, and the life of the pit very brief. The writer remembers well some quarter of a century ago being much interested in seeing an engine winding from a shaft situated several hundred yards away, and fixed, as it were, in a circle, with the engine as a centre, several other worked-out shafts, with which this same engine had dealt. Mr. Greenwell, in referring to haulage in his well-known and very excellent *Treatise on Mine Engineering*—written many years ago, when mining literature was scantier than now, and than which, amidst so many more modern publications, none are better even yet—gives some interesting facts as to the gradual development of haulage, and says, the various alterations and improvements which have taken place in the mode of conveyance underground from the face of the work to the shaft have contributed so materially to increase the quantities produced at individual mines that a brief sketch of them may not be inappropriate.

The first method which would be adopted is that which does not require any particular sort of carriage or description of road; a simple basket filled with coal and carried upon the back from the face to the shaft, and in some instances to the surface, constituting the whole apparatus. This rude system was prevalent in some parts of the United Kingdom till it was suppressed by Act of Parliament some forty years ago. The next means would appear to have been the wheelbarrow, which we discover by the old materials found in recently opened ancient workings to have been in general use about 200 years ago. Next came the sledge, or sled as it was more commonly called, which consisted of a wooden box resting upon iron shoes and drawn along the pavement of the coal, and these were probably in use well on in the last century. The next improvement was the substitution of planks for the floor of the coal for the sledge to slide upon; and the attaching of wheels to the sledge would soon suggest itself, thus giving us very nearly the tub now used, although it was a

long period before the tub came actually into use. After this came the application of corves and rolleys, one rolley being made to carry one, two, or even as many as six corves, drawn by one horse. Corves arranged in this way were found expensive and clumsy, and some fifty years ago coal tubs were very generally adopted, having sharp-edged wheels, and being placed upon rolleys, were drawn to the pit bottom. The uselessness of rolleys becoming more apparent, some ten years later they were abolished, and each tub was run upon its own wheels, which changed from the original sharp-edged tram wheel to the present flanged wheel, after the manner of wheels on surface railways.

Dr. Le Neve Foster also, in an excellently-written article on mining (which everyone interested in mining matters should read, as it is the production of one who knows exactly what he is writing about) in the edition now in course of publication of the *Encyclopædia Britannica*, refers to the same subject, and we need make no apology for using some of the interesting and valuable information therein contained. The only regret one has on reading this article is that it deals not too much with other kinds of mining, but certainly too little with coal-mining. Dr. Foster, so far as he is concerned, has done quite the correct thing in writing about that in which he is specially a proficient, and those responsible for the publication are simply following in the lines of our Science and Art Department, who year by year give Coal-mining something very like a second place at the examinations in mining. This may be both an appropriate time and place for suggesting to so august a body as the Science and Art Department that Coal-mining, being head and shoulders above all other branches of mining, should be for purposes of examination a separate subject, and that there should be associated with the examiners one or more practical mining engineers. The paper of questions given in mining this year (1884) did not contain a single one bearing upon the actual working of coal or the ventilation of mines. As regards the *Encyclopædia Britannica*, it is quite correct, as Dr. Foster was good enough to point out to the writer, that it does contain, in an article on Coal, much information on coal-mining.

But it does seem that so standard a work, read all over the world, should deal far more exhaustively with coal-mining in all its branches than its present article on Coal professes to do.

In future editions the article on mining should either be made so much more extensive as to allow coal-mining to be dealt with thoroughly, or, what would be even better, have a special article written by some unquestionable mining authority on the working and mining of coals in all the various mining and mechanical operations.

Dr. Foster says:—The simplest and oldest method of transport along underground roads is carriage on the back, and this method may still be seen at the present day, even in countries where the art of mining is generally highly advanced. The blocks of slate are carried on the back from the actual working place to the nearest tram road in the slate mines of the Ardennes. The system survives even in England in the Forest of Dean, where boys carry iron ore in wooden trays from the very irregular ore-producing cavities either to the surface or to the nearest shaft. The oldest form of wagon or tub is the German hund, which consists of a rectangular wooden body with four wheels resting on two boards as rails, and it is kept on the track by a pin which runs between the boards. Cast-iron tram plates were introduced in the last century, and were finally succeeded by iron rails, which are now in general use, although steel threatens to supersede iron in this as in other departments of mining, the usual form now being T-headed or bridge rails resting upon transverse or longitudinal sleepers.

In these advanced days, when collieries are arranged to clear out all the coals within possibly a mile round (many of our pits in various parts of the country go out much further than this, and some of the northern collieries are working nearly three miles from the pit shaft), with such a condition of things—the distance great, the daily output large, and the life of the pit extending over generations—it is of the highest importance that the arrangements for bringing the coal to the bottom of the shaft should be such as will deal effectively and economically with large quantities, that is, will bring the coal got from the working places to the pit bottom in such

quantity as may be required, and at the lowest possible expense. The writer was very forcibly struck in getting out some facts with regard to conveyance of coals upon the surface. In the old days preceding tramroads and railways conveyance cost about 1½d. per cwt.; in our day it has been reduced to less than 1d. per ton, and on that very substantial profits are realised.

The very best English work with which the writer is acquainted on haulage is the report of the committee appointed by the North of England Institute of Engineers. This tail rope committee, as they were called, because they were specially appointed at a meeting in Lancashire, held July 13, 1865, to enquire into and report on tail rope haulage, especially in various coalfields, comprised a considerable number of engineers, of whom the acting members were Messrs. W. Cochrane, G. B. Forster, John Daglish, Lindsay Wood, and R. F. Matthews. This committee extended the scope of its operations far beyond the original instructions, and were in a position nearly three years afterwards to present to their institute and the world the most complete report on haulage generally that has ever been made either before or since, and in 1871 it was translated into French by MM. Briart and Weiler, then engineers at the Mariemont Collieries in Belgium. The able engineer to the committee was Mr. Emerson Bainbridge, who unquestionably in that report laid the foundation of his afterwards and still very successful career as a mining engineer; and although a good share of a generation has elapsed, it still remains the work which contains more useful information than any other published in the English language, and the writer, whilst doing justice to his readers, will certainly not be affecting the fair fame of any of these gentlemen by making free use, with due acknowledgment, of the information which the North of England Institute spent a good deal of money in making known to the world, and which is now to be found in their *Transactions*. We are quite safe in saying that in the matter of giving reliable information on all practice connected with mining and machinery the North of England stands head and shoulders above all engineering societies throughout the world. The best foreign work on the subject, perhaps, is that in French by

M. Callon, the French Inspector-General of Mines, being lectures on mining delivered at the Paris School of Mines, and translated for our benefit into English by Mr. W. Galloway and Dr. Le Neve Foster, to which two gentlemen the mining world owe a deep debt of gratitude. From this work, also, we hope to obtain some useful information.

There is no intention of writing a treatise laying down a model system of haulage and hauling machinery, applicable to everywhere, and recommending its general adoption. That is neither possible nor desirable.

Whilst taking part in a meeting of an excellent mining institute some remarks were made laudatory of one district at the expense of another, and the writer took the opportunity of suggesting that comparisons in mining matters were not fair, and scarcely possible, and it was generally found that although different ways of doing the same thing prevailed in different districts, the engineers in each district might safely be trusted to adopt that which was best suited to the special necessities of their particular case.

It is proposed, however, to give some correct, and therefore useful, particulars as to the different systems, and it is not proposed to go into detail invidiously as to the comparative cost of working the various systems. No attempt has been made to get particulars of cost, because it is not necessary for the purpose of these articles, and such information is either not always obtainable or not always reliable. And in the matter of transmitting motive power to hauling operations there can hardly be any hard and fast rule laid down, because one colliery may be so fixed as to have it in its power to have a choice of means of transmission, whilst others are restricted in this respect, and this affords a strong argument against comparative costs, because such comparisons are worth nothing unless the cost includes first cost, cost of maintenance, cost of fuel, and wages; and one arrangement may be economical as regards first cost, but costly as to maintenance and wages, and *vice versa*.

Certain general principles, however, may guide us in all our hauling arrangements. They should be such as give a maximum of mechanical as against horse or manual

labour. No horses or men should ever be used in haulage —or, indeed, anything else connected with mining operations—that machinery can be made to do. To effect this, the haulage system must be in close proximity to the working places and lead right away to the pit bottom. The hauling arrangements should be such as will deal with considerably more than the highest possible output spread over the entire day, so that in the event of breakdown in any part of the system for any short period, the time, so far as hauling machinery is concerned, can be made up. This is simply adopting a principle in haulage already laid down for winding, steam generation, ventilating, and pumping—that in all colliery machinery we should have power enough and to spare. Then, as regards the special power to be used, we may have water power at our command. The colliery may have a very large make of water, to deal with which a very large pumping arrangement has had to be stationed at the lowest point, and to reach which a considerable portion of the water has to fall from a considerable height. In such a case this falling water should be made use of, because the power thus obtained is all clear gain.

The writer, now near upon twenty years ago, designed an arrangement for working hauling drums at a colliery in Wales by means of a turbine, and very good work indeed was done, and in more modern times excellent results have been obtained from hydraulic hauling engines. These, however, would be exceptional cases, as no one would think of taking water down to work an engine under ordinary conditions, because we should get less work out of it than would be needed to bring itself back. And as regards electricity as a means of transmitting power, the writer is not sufficient of an electrician to say whether that is going to benefit the mining world much for hauling underground. Electricians have yet to prove that to the satisfaction of practical men. The advocates of electricity as a means of transmitting power cannot expect mining engineers to accept their mere opinion that it will be found efficient. All new contrivances must rest upon their merits, they must be weighed in the balance of actual work done, and will be adopted just in proportion as actual proof is given that they are better, or at any rate as good in effi-

ciency and economy as the other systems so long in actual use. Up to the present time electricity has been useful at some collieries for purposes of light, but is nowhere as a transmitter of power.

So far as transmission of power is concerned, we are driven, as a general rule, to the adoption either of (1) steam actually generated below ground and driving engines there, (2) steam generated above ground and driving steam engines below ground, (3) air-compressing engines generating compressed air above ground to work hauling engines below ground, or (4) steam generated in boilers above ground driving steam engines also above ground. And it will be possible to show that not only have all these means of transmitting power supporters, but there are special cases adaptable to each. And there is one special condition exceedingly fortunate for the mineowner and engineer in which none of these arrangements are necessary, viz., when the pit shaft is sunk in a basin and the pit bottom is the lowest point of the basin. Then all the coal will fall to the pit bottom by self-acting gradients, and neither steam nor compressed air will be required to draw full tubs out or empty tubs in. Then, as regards the particular system of actual haulage, we must decide whether it shall be merely:—First, direct haulage with one rope, the empty tubs going back of themselves; second, tail rope haulage, having one rope to draw the full tubs out and another rope to draw the empty tubs in; third, an endless system, either, (1) with haulage rope below the tubs; (2) haulage rope over the tubs, or (3) an endless chain. It will be possible also to show that there are causes which govern the application of certain of these systems to certain places.

CHAPTER XX.

HAULAGE.—THE DIRECT SYSTEM.

Character of Roads—Construction of Tubs—Fast and Loose Wheels—Coning of Wheels—Friction of Wheel upon Rail and of Axle in its Bearing—What is Friction? Where Useful and where Injurious? The Laws of Friction—Co-efficient of Friction—Examples showing how Friction may be Increased or Decreased—The usual Co-efficient for Ordinary Colliery Tubs—Self-acting Haulage Arrangements—Jig Wheels and Jig Drums—Brakes for Jig Arrangements—Meaning of the Direct System of Haulage—Gradient to allow Empties to Run Back—Hauling Engines——Advantages of Horizontal Hauling Engines—Defects of Vertical Hauling Engines—Speed of Pistons in Intermittent and in Continuous Haulage—Hauling Engines working off First Motion—Hauling Engines with Spur Gearing—Example showing Size of Engines required to do certain Work—Example showing the Amount of Work certain Engines are capable of—Appliances to keep Hauling Ropes off the Floor—Rollers and Pulleys—Injury to Rope working on Floor or on Non-revolving Pulleys—Arrangement of Roller Pulley in Frame—Pulleys hung from Roof-Guide Pulleys—Arrangements for Rope passing round Curves—Changing the Direction of Hauling Rope—Endless Ropes of Self-acting Inclines—Tubs upon Heavy Gradients—Appliances for Holding the Gang when Rope breaks—Difference of Breakage with Descending Gang as compared with Ascending Gang—Importance of High-class Materials in Ropes and Chains and Drawbars and Cappings—M. Callon's Lectures on Mining—What is a Safe Load for Ropes and Chains? The Materials of which Chains and Ropes are made should be Tested—Ropes and Chains should never be Over-worked.

It is not proposed to say much as to the character of roads underground upon which the tubs have to run. For light loads and slow speeds roads very roughly constructed answer the purpose, but for heavier loads and the high speeds of direct and tail rope haulage, road-

making is not a matter to be neglected. It may just be said that in all cases the roads should be well made and kept fairly in repair, and the curves, where inevitable, made as easy as possible. Tubs sometimes have their wheels fast upon them and sometimes loose. For the very high speeds of surface railways we always find wagon wheels fast upon their axles, and their adaptability to curves is effected in another way. The wheels are coned so that in passing round a curve the outer wheel is running upon a larger diameter than the inner wheel, and so straining the machinery and skidding of the wheels is avoided, and no doubt for this work on really well made railways and very large curves, this system of fast wheels is the best. It has not always been universally admitted, nor is it yet, that the coning of railway wheels answers the intended purpose. The late Sir Charles Fox, an engineer of no mean repute, wrote many strong letters to engineering journals with a view to show that wheels should be parallel and not coned. Probably there is not so much in it as some have argued; there is, however, some advantage in it on railways. But underground it is different, and for the necessarily sharp curves and for easy adjustment from one road to another loose wheels afford advantages.

Neither do we purpose speaking as to the construction of tubs. In the matter of shape and construction each district has been guided by its own necessity and experience. But a very material matter with which we are bound to deal is the frictional resistance to the motion of tubs, whatever be the system of haulage adopted. This friction may arise and does arise in two ways—namely, from the friction of the wheel upon the rail and the friction of the axle within its bearing. Theoretically, the friction of the wheel upon the rail, if the road is perfectly even and the wheel perfectly round, ought not to be, because the wheel simply rolls upon the rail. But the rail is never perfectly even, and the wheel is never perfectly round, and there is some rising and falling and some slipping and skidding, so that apart from the action of the axle within its bearing there is some resistance. However, it is not great in proportion to the whole, and we prefer to leave it out of consideration and make

sufficient allowance in the other resistance to cover this also.

And now, first of all, What is this friction? and What do we mean by it? That it is not universally understood is certain, else would-be discoverers of a perpetual motion would cease from troubling and resolve to be at rest. Friction is a term used to denote resistance to motion which is brought into play when two rough surfaces are moved one upon another. We say rough surfaces because it applies especially to very rough surfaces, and all surfaces as contrasted with the smoothness of theory may be considered rough. Friction is not a force but a resistance which absorbs work and neutralises the action of force. In some cases it is exceedingly useful, such as in brakes for winding engines and locomotives and many other machines; also in the arch, which would not stand, and the nail and screw, which would be useless without it. In other cases it is a source of waste and expense. In the parts of machinery where pieces are revolving or moving upon each other friction is a direct loss of power, and the object of an engineer is to lessen it as much as possible.

Friction is the resistance which one substance opposes to another substance passing over it, and there are three well-defined laws of friction, namely, first, the friction between the surfaces of the same kind is in direct proportion to the pressure between them. Second, the amount of friction is independent of the extent of the surfaces in contact. Third, the friction is independent of the velocity when the body is in motion.

The co-efficient of friction is a constant number representing the proportion between the friction and the pressure between two surfaces when the surfaces are of the same material and in the same condition.

The numerous experiments made have given somewhat different results, but a fair average for metal on metal with oil is 0·1 or $\frac{1}{10}$. The friction then of an axle in its bearing depends on the co-efficient, but it also depends upon something else, namely, on the extent of surface that the resistance operates upon. Suppose, for example, the head-gear pulleys at a colliery 12 ft. diameter, with bearings 6 in. diameter, and the average weight upon the pulley 5 tons, and the depth of the pit 500 yards; 500

yards = 1,500 ft., and 12 ft. diameter = 37½ ft. circumference 1,500, 1,500 ÷ 37½ = 40, showing that a 12 ft. pulley would revolve forty times each winding. So would the bearings, which are 6 in. diameter = nearly 19 in. circumference. The bearing has a circumferential surface $\frac{1}{24}$ of the pulley and we take the co-efficient of friction 0·1. The weight is 5 tons = 11,200 pounds ÷ 10 = 1,120 pounds × (1,500 ÷ 24) or 62½ = 70,000 foot pounds of work, the resistance of the bearing.

The actual load is 11,200 × 1,500 = 16,800,000 foot pounds useful work, and 70,000 foot pounds being $\frac{1}{240}$ is extra power required because of friction on the bearing.

Now we will increase the wheel to 18 ft. diameter and reduce the bearing to 4 in. diameter:—18 ft. diameter = 56½ ft. circumference; 1,500 ÷ 56½ = nearly 27, showing that an 18 ft. wheel would revolve twenty-seven times for a winding of 1,500 ft.; 4 in. diameter = 12½ in. circumference, or $\frac{1}{54}$ of the circumference of the 18-ft. wheel; so that in a winding the circumference of the bearing will travel 1,500 ÷ 54 = about 28 ft. The co-efficient of friction is as before, 0·1, and the average weight as before, 5 tons = 11,200 lb.; and the useful work in raising 11,200 lb. 1,500 ft. = 11,200 × 1,500 = 16,800,000 as before; but the resistance on the bearing is 16,800,000 ÷ 10 = 1,680,000 ÷ 54 = 31,111 foot pounds, reducing the resistance by more than one-half. A wheel whose axle was a theoretic line would absolutely experience no resistance at all. From this we learn that not only should we make the co-efficient of friction as small as possible, by having well-turned axles and well-bored bearings, and a good lubricant, but we should lessen the travel of the axle upon the bearing as much as possible by having the axle small and the wheel large. For headgear pulleys we have plenty of room, and may make the pulley any diameter up to 20 ft., and the axles should be made as small as possible consistent with the load they have to sustain. In tubs for colliery purposes the size of the axles is regulated in the same way, and when made of good iron—or what is even better, good steel—need not much exceed 1 in. in diameter for a gross load of half a ton. The wheels are in most cases made small in diameter, as the height of the mine is limited, and diameter of the wheels

reduces available depth of tub. But supposing a well-turned axle in a neatly-bored pedestal and well greased, and a co-efficient of friction 0·1, as before, and with axles 1 in. diameter, and wheels 10 in. diameter, what force should be required to move a tub upon a level road? The bearing is to the wheel as 1 to 10, and with a co-efficient one tenth, 1 lb. should move 1 cwt.

As a fact, the axle is always greater in diameter than 1 in., and often enough is not turned at all, nor the pedestal bored, and the oiling always performed roughly and rudely. Experiments have shown that with a tub in good condition, with wheels about 10 in., and axles about $1\frac{1}{4}$ in., working upon a level road in good order, the moving force required is about 1 lb. in 56 lb. But in a mine it is not easy to keep tubs in good running order, and roads are dirty and dusty and sometimes wet, and this allowance of 1 lb. in 56, being 2 lb. per cwt., is scarcely enough, and the writer prefers in calculating as to haulage to allow 1 in 28, being 4 lb. per cwt. Experiments to find the friction of tubs showed $\frac{1}{65}$ as the average co-efficient with a gross average load of 1,033 pounds, a co-efficient of $\frac{1}{70}$ for a load of 607 pounds, a co-efficient of $\frac{1}{68}$ for a load of 351 pounds, and a co-efficient of $\frac{1}{58}$ for a load of 265 pounds, and this variation although the same road was used for all the experiments, and all the wheels and axles were uniform in dimension.

Another series of experiments showed an equal amount of uncertainty, the co-efficient coming out as high as $\frac{1}{32}$, and as low as $\frac{1}{60}$. Taking everything into consideration we had better allow for friction, as has been given above, 4 pounds for each cwt.

When the pit bottom is the lowest point of the mine, and the workings rise from it on the various sides, the manager is happy and the proprietor is blest, especially if the rise is not so great as to make the descent of the loaded tubs dangerous. We may assume as an accepted fact that at an inclination of one in thirty tubs will run by gravitation, anything less than this, power will be required to move them, and anything beyond this is an inclination that is not desired.

For lowering coal to the pit bottom we may use jig wheels with the axis vertical (see fig. 138), or jig drums

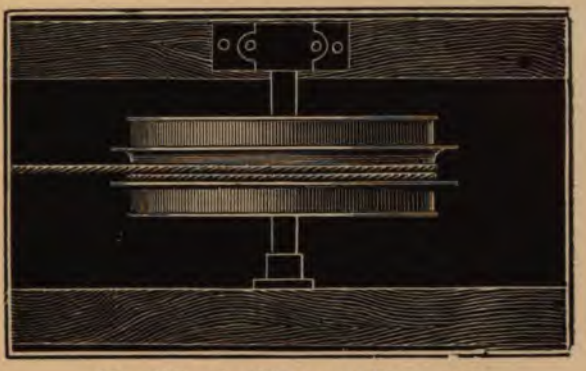


FIG. 138.—JIG WHEEL IN ELEVATION.

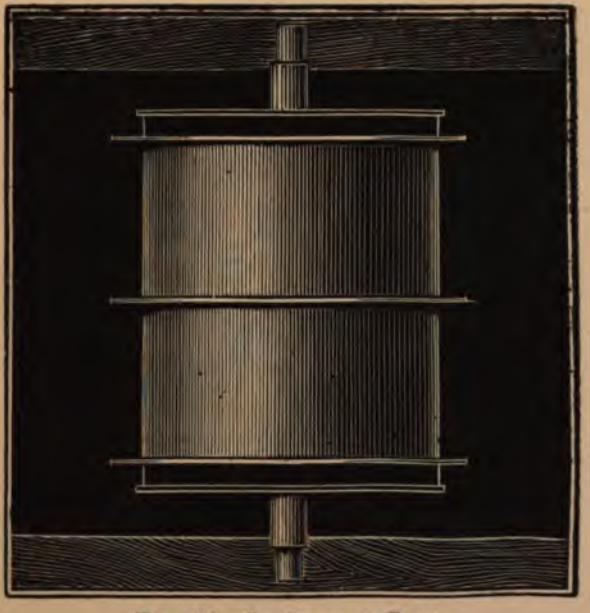


FIG. 139.—JIG DRUM IN PLAN.

[*To face page* 218.]

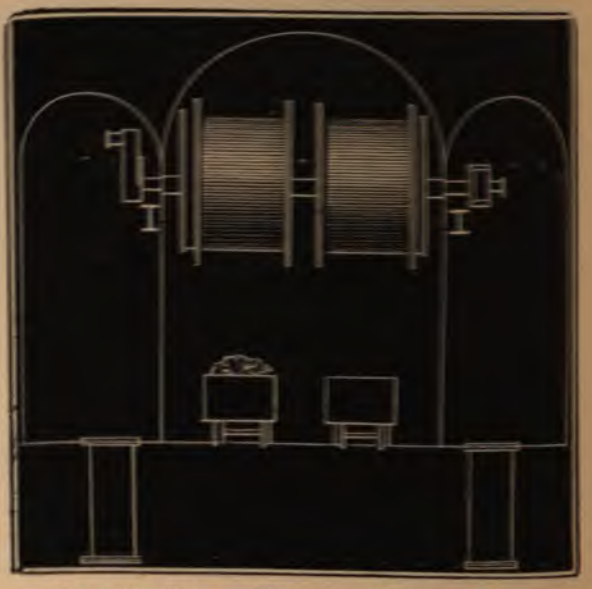


FIG. 140.—PAIR OF VERTICAL HAULING ENGINES.



FIG. 141.—PAIR OF HORIZONTAL HAULING ENGINES.

[*To face page* 213.]

with the axis horizontal. (See fig. 139.) In either case the essentials are a reasonable diameter for the rope to coil upon, and a brake of sufficient power to stop the gang at any point. It has been stated in these articles that in large winding drums a brake all round is undesirable, inconvenient, and unnecessary, indeed the best winding drum brake is the Burns, applied only at a small part of the bottom of the circumference. For small wheels and drums all-round brakes are the best, because in addition to the friction of one surface upon another an all-round brake has an enclosing kind of grip not obtainable in any other way. A good pliable wrought iron brake strap lined with flat hemp rope acting upon a turned iron surface will do well if the bolt heads attaching the hemp rope to the brake strap are kept clear of the brake ring. One unfortunate bolt head rubbing on the brake ring destroys the efficiency. It is more than questionable whether in ordinary brake arrangements for winding or for hauling anything is really superior to hemp rope upon iron. There is considerable wear, but a new hemp rope is easily attached. The keeping bolt heads free from the drum ring is important, and is easy enough with careful examination. But sometimes such care is not exercised, and even fatal accidents have been caused, because when great brake power was needed a bolt head intervened and made the brake useless.

Coming to the systems of haulage where power is required, the simplest is that which will make all direct haulage—namely, in which one rope only is used and that to draw the loaded tubs to the shaft, the empty gang afterwards falling by gravitation. To accomplish this the fall from the pit must everywhere exceed 1 in 30. For this system of haulage we require small winding engines which may either be vertical, as shown in fig. 140, or horizontal, as shown in fig. 141. In the former case the engineman practically sees only one engine and is out of the line of work. Also each engine supports itself and its shafts by means of girders which are liable to break by settlement.

The writer had an actual experience of the troubles peculiar to vertical hauling engines. Settlement caused the engines to get out of perpendicular, and they worked

badly, the piston rubbing against one side of the cylinder, and the piston rod against one side of the stuffing box, causing excessive friction and injurious wear. Then the girder upon which one end of the beam and crank shaft rested gave way, necessitating considerable repair. The frame having become relieved would badly and bind, and the work of remedying these defects would have been as great as erecting the engines at first.

In the latter case timbers are thrown across the working way, the engine rests upon them, the engineman has the whole of the machinery under his eye, and exactly what he is doing and settlement has little or no disturbing influence. In horizontal engines, resting as it were in one compact piece upon timber framework, there is no difficulty, even if settlement does take place in raising the sunken side to the original level; and the being able to examine and oil the whole of the machinery without the awkward necessity of leaving an engine house and crossing over a working way is an arrangement of unquestionable advantage.

For direct haulage it may be said that, as in winding, the engines should be horizontal and work in pairs. Now as to being on first motion without spur wheels the drum or drums being on the same shaft as the cranks, or on second motion with spur wheels we have both types. Everything depends on the size of the drum and the speed at which we wish to work. A hauling engine *running continuously* should not have a piston exceeding 250 ft. per minute, but for intermittent haulage we may well enough increase the average piston speed to 350 or even 400 ft. per minute.

We will suppose hauling engines 3 ft. stroke, and a drum 4 ft. diameter = 12½ ft. circumference. The rope will travel 12½ ft., while the piston travels 6 ft., and if the piston travels 400 ft. per minute the rope will travel $400 \times 12\frac{1}{2} = 5{,}000 \div 6 = 867$ ft. per minute $\times 60 =$ 52,020 ft. per hour $\div$ 5,280 = nearly ten miles an hour. In such a case, if we wished so high a speed as this—and direct haulage must almost necessarily be quick, being intermittent—spur-gearing would not apply, because wheels are used in haulage, if at all, to lessen the speed and increase the power. If the drum is 6 ft. or 8 ft. in-



Fig. 142.—Drum Lagged with Timber.



Fig. 143.—Drum Lagged with Iron.

[*To face page* 221.]

stead of 4 ft., or if the speed required is five or six miles instead of ten, then spur-gearing comes into play, enabling a smaller engine to do the work. There are advantages in hauling engines working direct; we simplify the machinery, we avoid clanging and clashing—inevitable with wheels—and the brake acts directly upon the engine itself. If the drum is large the brake is sufficient on the under part of the circumference; if the drum is small, an all-round brake is a benefit. Formerly hauling drums were lagged with wood (see fig. 142); now many are lagged with iron (see fig. 143). In point of weight there is nothing in it, as ½-in. iron lagging will be about the same as 4-in. wood lagging. Many think that wood is best, as it injures the rope least; but there is not much in this, and in any case on most hauling drums a rope has to coil upon itself with no wood between. Iron lagging gives more room inside the drum makes a stronger structure, and will last for ever.

When a drum is truly circular the rope will give good results upon it, whether lagged with iron or with wood. The argument sometimes raised against ropes running upon iron will not hold good, because it has been proved that even in winding appliances ropes coiling upon drums and working in grooved iron, as described and illustrated in Vol. I., chapters on winding appliances, have a longer life than the same ropes running upon wood. For hauling drums, iron lagging can be put on in two pieces, and answers admirably.

Suppose we knew the quantity to be dealt with, 500 tons in ten hours over a distance of 2,000 yards up an inclination averaging 1 in 10, with available steam pressure 30 lb. effective on the piston, and we want to determine the size of engines required. We fix the average speed at six miles an hour, and the drum 5 ft. diameter, and the engines being a pair to work on first motion. We assume a stroke of 30 in.; six miles = 5,280 × 6 = 31,680 ft.; 2,000 yards = 6,000 ft. The time occupied in making a journey one way is found as follows:—As 31,680 feet, amounting to six miles an hour—which is the speed—is to 6,000 feet—which is the distance to be traversed—so are 60 minutes to 11⅓, say 12 minutes. Each gang occupies 12 minutes each way = 24 minutes, and 6 minutes' inter-

val = 30 minutes for each journey, amounting to two journeys per hour, or twenty journeys per day; 500 tons ÷ 20 = 25 tons per journey. Suppose each tub to carry 10 cwt.: this means 50 tubs, and if each tub weighs 4 cwt. we have 25 tons of coal and 10 tons of tubs = a gross load of 35 tons ÷ 10, the inclination being 1 in 10, = a net load of 3½ tons. For this a rope weighing 4 lb. per yard would probably be required, which for the total length would equal 8,000 lb. We are assuming that none but the highest quality of material is used for ropes. It has been repeatedly in these chapters, and it cannot be too often, urged that it is weak and wasteful in the highest degree to use other than the best ropes for winding and for haulage. This rope that we have selected, weighing 4 lb. per yard, would, if made of best improved steel, have a safe working load of six tons, which, as will be seen presently, allows a considerable margin of strength over and above the actual work to be done. The weight, 8,000 lb. ÷ 10 = 800 lb., and the net load, exclusive of friction, becomes 3½ tons = 7,840 lb., representing the tubs and coals, + 800 lb., representing the rope = 8,640 lb. acting at the circumference of a drum whose circumference is 15·75 ft. But we must add to this the friction, which is taken at $\frac{1}{28}$ of the gross load. The rope weighs 8,000 lb., and the tubs weigh 10 tons, = 22,400 lb., and the coals weigh 25 tons, = 56,000 lb., making a total gross load of 86,400 lb. ÷ 28 = 3,086 lb., the allowance for friction, which, added to 8,640, = 11,726 lb., the actual load upon a circumference of 15·75 ft., 11,726 × 15·75 = 184,754, the moment of load. The power is the pressure upon the piston, and its leverage is the double stroke of the piston, 5 ft. 184,754 ÷ 5 = 36,951 ÷ 30 lbs., the effective pressure of steam upon the piston = 1,232, which gives us theoretically the required piston area in square inches. To this we add our unvarying half for general resistance and surplus power, making the required piston area 1,848 square inches for one cylinder, and ÷ 2 = 924 square inches for each cylinder of a pair. A piston 924 square inches area is 34½ in. diameter, showing that we should require a pair of engines on first motion with 34½ in. cylinders and 30 in. stroke, working a drum whose diameter is 5 ft. The cylinders and stroke are evidently not proportionate,

and to remedy this we simply find another proportion in which the area of cylinders × the stroke will give us the same power. This we obtain with cylinders measuring 27¼ in. and 4 ft. stroke, being pretty nearly the orthodox proportion of 1 to 2. In this example our piston speed would come out nearly 270 ft. per minute, being considerably under a fair allowable speed for direct hauling engines.

Now, taking an example the other way. Suppose we have a pair of hauling engines with stroke 4 ft. and cylinders 24 in. We can rely upon an effective pressure of steam on the piston of 30 lb. per square inch, and propose to run at an average piston speed of 400 ft. per minute, and propose that the tubs shall have an average speed of eight miles an hour. If there is no spur gearing, what size of drums shall we require, and how much coal can we deal with in one hour from a distance of 2,500 yards, the average fall from the pit being 1 in 9? First let us get the power upon the pistons; 24 in. diameter = 452 square inch area × 30 = 13,560 × 2 = 27,120, and deducting one-third for frictional allowances, 9,040, leaves an effective power of 18,080 lb. travelling at 400 ft. per minute. The tubs have to travel eight miles an hour = 42,240 ft. ÷ 60 = 704 ft. per minute. While the piston travels 4 × 2 = 8 ft., the crank travels 4 × 3·1416 = 12·5664, say 12½ ft.; and while the circumference of the drum travels 704 ft., the piston travels 400 ft., and the crank travels 625 ft. Therefore, as 625 is to 704 so is 12½ to 14 ft. circumference = 4½ ft. diameter of drum. The load × 14 must equal the power, 18,080 × 8 = 144,640 ÷ 14 = 10,331 lb., the load with which these engines are capable of dealing. We must now proportion this load so as to allow for weight of coals, weight of tubs, weight of rope, and friction. The rope will, as in the previous example, probably weigh about 4 lb. per yard × 2,500 = 10,000 lb., and this divided by the inclination, 9 = 1,111 lb., which, deducted from the load, 10,331 lb., leaves a balance of 9,220 lb.; this × 9, the inclination, = 82,980 lb. The tubs when empty will probably weigh one-third of the load they carry—namely, 82,980 lb. ÷ 4 = 20,745 lb. tubs and 62,235 lb. coals. But as yet we have allowed nothing for friction, which is $\frac{1}{9}$ of the gross load—namely, 10,000 lb. rope + 82,980 lb.,

tubs and coals = 92,980 lb. ÷ 28 = 3,320 lb., the allowance for friction, which must be deducted from the effective power available for tubs and coals, 9,220 lb. = 5,900. This we multiply by the inclination, 9 = 53,100, and dividing as previously by 4 = 13,275 lb., weight of tubs, and 39,825 lb. coals. The speed of the rope is eight miles an hour = 704 ft. per minute, and the distance being 2,500 yards = 7,500 ft., we shall occupy 7,500 ÷ 704 = 16½ minutes each single journey × 2 = 33 minutes each double journey; and allowing intervals amounting to seven minutes, that means one and a-half journeys per hour. The load of coals is 39,825 lb. × 1½ = 59,737 lb. ÷ 112 = 533 cwt.—say, practically 27 tons per hour. Showing that with a pair of engines having 24 in. cylinders and 4 ft. stroke, running 400 ft. per minute, and drums 4½ ft. diameter, and having effective steam pressure upon the piston of 30 lb. per square inch, we could deal with 27 tons of coals per hour from a distance of 2,500 yards, the average inclination being 1 in 9.

In all haulage arrangements, direct or otherwise, means must be adopted for keeping the rope off the floor. Some systems will, if properly worked, in themselves effect this, the tubs forming the support; but in direct haulage the rope has no supporting influence except its own tension, which for this purpose is useless. Pulleys must be placed, and at no great distances between, and such pulleys must be kept in working order. We may almost as well have the rope cutting into the metal of the floor of the mine as cutting into the metal of the pulley; and when a pulley is broken or worn through, it must not only be removed, but a new one inserted in its stead. These seem simple instructions enough, but the neglect of them not only throws a heavy expense upon the colliery for ropes, but leads at times to accidents with tubs, and even with workpeople. The wear upon a hauling rope working properly, and the work confined to drawing the actual load, is as nothing compared with the work entailed by wearing a groove in each of a whole range of pulleys. And these grooves being worn, there is the constant danger of a strand of the rope being torn out, and then of course the rope is destroyed.



Fig. 144.—Roller Pulleys fixed on the Floor, say about 20 Yards apart.



Fig. 145.—Showing Roller Pulley and Frame in Position.

[*To face page* 225.]

When the gang has to be drawn right up to where the engines stand, or nearly, the rope must, of course, be able to work all the way, and the pulleys will have to be placed upon the floor, as shown upon fig. 144, and in such a case a simple pulley arrangement (see fig. 145) may be used in which the timbers on which the pulley rests also answer as sleepers for the rails. The height at which these pulleys are placed will depend upon the clearance under the tub, which is regulated by the size of the wheels. The couplings, &c., jangling over the pulleys will do no harm, but the fixed portions of the tubs should be well clear. It is not essential that these pulleys should be turned in the lathe; they should, however, be cast as round as possible, and have a hard, smooth surface. The small pedestals should be bored, and the axles, which should be as small as may be consistent with safety, should be nicely turned. In the calculations as to friction in haulage, we have allowed, and shall allow, a large co-efficient, because, probably, whatever may be said here, that care with tubs and ropes and pulleys will not be exercised that might be and ought to be to lessen the friction. All the same, whilst allowing a large co-efficient, it has been thought well to show how good engineers and careful managers may materially lessen it. Good results may often be derived by having in front of each hauling drum a kind of guide pulley, which, sliding about freely on its axis horizontally, helps the rope to lap properly upon the drum. In the winding drum this difficulty is avoided, because we have not that great distance with a small drum which needs coil upon coil to find room for the rope; but in haulage, when two or three thousand yards of rope have to find room on a drum not exceeding 5 ft. or 6 ft. diameter, and necessarily only narrow, this is unavoidable. A guide pulley will in this matter tend to keep the hauling rope in the right line for haulage, and also to help it to coil properly upon the drum. The proper coiling of a hauling rope upon its drum considerably prolongs its existence, whilst rough and careless coiling results in serious injury and a shortened life. When the loaded gang has to be brought to the position of the engines in a straight line there is no trouble; horizontal pulleys on the floor all the way answer the purpose, with the addition, prob-

ably, of one raised guide pulley, as just named. Should bends occur here and there, side or vertical pulleys may require to be placed in the roadway, the object, of course, being always to keep the rope in its correct line of action. And when a curve almost or quite at right angles has to be dealt with, then a complete arrangement of vertical pulleys fixed round the side, as see fig. 146, may be required. In such a case, however, much care in fixing and power in working may be required. There is great resistance to motion at this point, and the only thing is to make the curve as easy and the pulleys as large as may be. There are cases where the direct hauling engines do not draw the loaded tubs right away to the pit bottom, or where the engines stand but up heavy inclines to an intermediate point, from which they are conveyed along an easy road by some other means. In such cases the rope will be conveyed upon pulleys supported from the roof (see fig. 147) to the point where the engines finish their work, and the rope will generate considerably less friction, because rubbing on the floor is out of the question. These hanging pulleys do their work admirably, because they are more easily kept in working order and much less liable to become clogged in the journals than are pulleys placed upon the floor. And should a curve, as has just been named, have to be dealt with, instead of a number of comparatively small pulleys fixed against the side, one large pulley will answer the purpose and proportionately reduce the resistance. (See fig. 148.) Such an arrangement would come in very effectively, where, say, at the end of a long level several roads branched out, all dipping considerably. The powerful hauling engines could be used in turn to draw gangs out of these places, and they could be sent along the level to the cage by some other less powerful means. The writer knows at least one colliery so circumstanced, in which for some 700 yards from the pit bottom, the drawing way is level, and at the far end, there are branches dipping as much as 1 in 4 and 1 in 6. Hauling engines powerful enough to draw the needful loads up such heavy inclines are simply wasting time in being used to work upon the level. And still they must be situated near the pit shaft, for two reasons, namely, to avoid the loss of power which must result from

conveyance of steam so far, and to make it practicable to deal with the exhaust by turning it direct into the sump. Consequently, they have their rope conveyed from the roof along the level, they haul up the inclines, and an endless system requiring scarcely any power at all does the haulage on the level.

Before leaving the subject of self-acting inclines, we might have mentioned that a continuous or endless rope may be used, passing round a pulley both at its upper and lower ends. The pulley at the higher end will be fixed and the pulley at the lower end adjustable upon some kind of movable frame or carriage, so that the tension on the rope can be regulated. The brake on these self-acting arrangements may be arranged so that it is either held against the rim by a weight when at rest, or, on the contrary, is loose when at rest and not tightened up until the brakesman moves it as he finds necessary. Of the two arrangements the first seems to have some advantages, since it offers a guarantee against negligence on the part of the workman, because the machinery cannot be set in motion without the intervention of the brakesman, who starts it by lifting the handle; he moderates its speed by allowing the strap to press somewhat on the brake-wheel, and, lastly, he stops it altogether when he lets go the lever and allows the counterbalance to exercise its full force.

The same kind of principle was at one time, and may be yet, carried out in connection with brakes to winding engines. The steam brake was so arranged that a weight kept the brake on and steam pressure was required to take the brake off. The idea was that if an engineman inadvertently or even purposely turned off the steam at the boilers he would not, by so doing, take the power off the brake and, as has happened in several cases, allow the cages to run away. The objections to such an arrangement for winding engines were and are, first, a steam brake on a winding engine should really only be used on an emergency, and in such a case the sluggish action of a dead weight compares unfavourably with the instantaneous operation of live steam; second, a fixed brake-power must be determined, that is, there must be a pressure of steam at which the brake can be removed. This

necessitates the pressure, and accordingly the brake-power, being fixed low enough, otherwise there will be seasons when the engine cannot be started because the steam is not high enough. Such a condition of things sometimes might be serious, and always awkward. For winding-engines, the steam brake, if used, should be such as allows a dead weight to take it off and live steam to put it on, thus increasing the power as the steam pressure rises, when, of course, greater power is needed, and also affording all the advantages of the quickness of steam action. But for self-acting inclines the brake applying itself does not seem a bad thing.

We may also mention here arrangements which may be made for preventing the accidents and disorders caused by the breakage of either an ascending or a descending rope. Scarcely a month passes but some accident causing loss of life occurs through breakage of a rope or a chain on an incline. First and foremost is the use of good materials in chains, and drawbars, and ropes, and cappings. Secondly comes careful inspection, and recent investigations into an accident which resulted fatally would seem to show that the mines' regulations require exactly the same daily inspection of chains and drawbars of tubs as are always given to chains of winding ropes. But even the very best materials and even the most careful inspection do not prevent accidents, although they go a very long way towards it, and some safety appliances or other are in common use.

With an ascending rope it is not difficult to apply something. A kind of fork with two long prongs (technically described in some districts as a "devil"—although why it should be so called, having been the means of saving many a life, it is hard to say) is fixed behind the last tub. It trails on the ground while the gang is ascending, and at once stops it by digging into the ground if the gang attempts to run backwards. (See fig. 149.)

The stoppage is effectual, because as the wagon has acquired a certain amount of momentum in going upwards, it has not time to acquire any velocity downward before the catch comes into operation. With a descending gang it is different, because after the rope or chain breaks the velocity is in the same direction as before. A

contrivance known as a bridle chain is used for both ascending and descending gangs, and is a very excellent safeguard in the event of a coupling or drawbar breaking, and these are much more likely to give way than a rope. This bridle chain is attached behind the last tub going up, which is, of course, the first coming down, and, passing under the entire gang, is connected to the hauling rope at the other end of the gang. This bridle under ordinary work has nothing to do, therefore is not liable to those jerks which kill the links of a chain, and when a coupling or a drawbar gives way and allows the gang to separate in two, the bridle chain comes into operation and all goes well. (See fig. 150.)

The writer was engaged in one case a very short time ago, when it was proved to the satisfaction of judge and jury that the use of such a contrivance would have saved life. And one sad feature in the case was, it was proved in evidence that such an appliance was at hand, and not only might have been used, but the neglect to use it was a disobedience of orders. But with a descending gang, when the rope itself breaks or draws away from its capping, the ordinary fork arrangement will not do, and the bridle chain is useless.

What we require is a contrivance such as the fork, for example, which, held up out of the way whilst all goes well, drops into position immediately the tubs break loose. There are two ways of accomplishing this—a gang rider on the first descending tub might bring the fork into action when the gang breaks away, but there is the danger that by trying to save life in this way we might destroy it, and the stoppage of a gang running down hill at a high speed would certainly endanger, and might kill, the unfortunate attendant. It might suggest itself that with an attendant riding on the first tub, that is, a gang rider, a brake which such a person could apply not so suddenly as a fork, still quickly enough to prevent a runaway, would answer the purpose.

No doubt such an appliance might do where the inclination was not so very great, and where perhaps only one or two tubs got away; but where such an appliance is most essential—namely, on a steep incline, where perhaps nearly an entire gang gets away, a brake arrangement on

any one tub would not exert sufficient power. Or we might, by a bridle chain passing over the tubs, attached to the fork at one end and to the hauling rope at the other, keep the fork up while the tension was upon the rope, and it would fall into position when the rope gave way and the tension was removed. (See fig. 151.) Such an arrangement scarcely commends itself as a real safety appliance, the difficulty, as with many other so-called safety appliances, being that it would probably act when it ought not to do, and thus cause disaster which its design would be to prevent.

Safety appliances are those which cannot fail at the right time and cannot come into operation at the wrong time. But from ideas casually suggested in even a cruder form than this ingenious appliances have been designed which have saved many a valuable life. M. Callon, in his *Lectures on Mining*—from which excellent work much material has unhesitatingly been drawn for this and other chapters—gets out of the difficulty by saying that it is not usually the descending rope that breaks. This is so, no doubt, and the great majority of accidents with ropes and chains must and will occur with ascending loads—the jerk and the strain are greater; but accidents do happen and have happened very recently—at least three times within as many months—in which lives have been lost with descending loads, and appliances to prevent them are requisite. The records for a period of one year of ropes breaking are really distressing; and although all could not by any possibility have been foreseen, most of them may be pronounced avoidable accidents. Our improved qualities of material all amount to nothing if the workmanship is defective, but probably more fail through bad manufacture than bad material; and high quality of material and make amount to nothing if the working load is greater than the safe burden.

The important question may be raised, What is a safe load for ropes and chains? In the matter of chains we have ventured to copy a simple practical rule from an excellent work by a high authority, to the effect of squaring the diameter in eighths of an inch, mark off the last figure as a decimal, and the result gives the safe working load in tons. And this rule has not been received with general

acclamation. It has been spoken of as fixing too high a load, and, on the other hand, as determining too low a load. The rule certainly assumes all chains to be manufactured from iron of exactly the same quality, which is certainly not the case. We have chains of poor iron on which the rule will fix the load too high, and we have chains of specially good iron on which this rate will not allow a load nearly large enough. The writer's attention has been drawn, at one of the most important collieries in Scotland, to the working of a hauling chain the breaking strain of which has been proved to be nearly 46 tons per square inch. (This endless chain arrangement is so excellent in many respects, and is so well adapted, and doing such excellent work, that in these chapters treating upon endless haulage it will be fully referred to. An endless chain working over more than a mile of road, and dealing with 25 tons each journey up an inclination the whole way of 1 in 15, is not seen in every part of the United Kingdom, and the writer was exceedingly pleased to have the opportunity of thoroughly inspecting it.) It would be scarcely fair to only allow the same load upon this as if the breaking strain were only one-half. In the manufacture of chain a piece of every bar should be tested for tensile strength and ductility, the object of the latter being to prevent the sudden shocks inevitable with non-ductile iron, and which are ruinous in chains. Having determined the breaking strain, we might fix upon a working load not to exceed one-fourth of that amount. Then, as regards strength of ropes, the particulars furnished on the cards of manufacturers can hardly be considered reliable, not being the result of actual experiment. The wire, probably, is and ought to be tested. A rope should be made exclusively of one quality and make of wire, and a piece of each rope, which we assume will be made exactly the same all through, should be cut off and tested, and the breaking strain and working load should be determined. In no case should a rope or a chain upon which lives depend be overworked. No sign may be given of impending danger; but one sad day an overworked rope smashes and causes destruction to life or property, or both.

Probably in some parts of the mining world where these chapters are read more than one inventive genius

may have introduced and have in actual operation an ap
pliance safe and simple and effective, which does in haul
ing appliances all that need be required. If not, possibl
this reference to the subject may do something toward
producing such a contrivance.

We want means for preventing either an ascending o
descending tub running far after breaking loose.

CHAPTER XXI.

HAULAGE.—THE TAIL ROPE SYSTEM.

What is the Arrangement known as Tail Rope?—Its Importance and Popularity in the Northern Coalfields—The North of England Institute—The Report—G. H. Wright—Emerson Bainbridge—G. C. Greenwell—Mr. Berkeley—Tail Rope Haulage at the Marley Hill Colliery in County Durham—Advantages and Disadvantages of Hauling Engines under the Roadway—Length of Rope in Tail Rope Haulage—Rollers and Pulleys for supporting the Hauling Rope—Bringing Loaded Tubs out from various Stations—Useful Effect at Marley Hill Colliery—Mr. Greenwell's Co-efficients of Friction—Speed of Marley Hill Haulage—Loss of Steam Pressure in Travelling through 200 Yards of Pipes—Cost of Conveyance of Coals—Advantages of Steam Receivers—Advantages of Receivers when working with Compressed Air—Comparison in Cost as between Horse and Mechanical Power for Haulage—The Tail Rope Arrangement in its Simplest Form—Results of Reading and Discussing Mr. Greenwell's Paper—High Appreciation of North of England Haulage Report—The North Hetton Colliery—Nicholas Wood—George Stephenson—Haulage Arrangements at Hetton—High Speed—Arrangements at Seaham—Description of Engines and Boilers—Indicator Experiments—Arrangements at Seaton Delaval—Low Useful Effect—Probable Defective Arrangements for the Ropes—Arrangements at Harradon Colliery—Description of Engines and Boilers—Indicator Experiments—Useful Effect—Murton Colliery—Special Arrangement of Friction Wheels for working a Pump—Advantages of the Appliance—Indicator Experiments—High Useful Effect and Low Expenditure of Power on the Engines—Experiments to find Friction of Tubs—Cost of Leading Coals at Murton, and Harradon, and Seaton Delaval, and at Seaham—Summary of North of England Report—Leading Features of Tail Rope Haulage—Disadvantages of the Tail Rope System—Usual Appliances—Loose Running Drums—Curves can be worked on the Tail Rope System—Methods of attaching Branch Ends to Main Rope—Methods of Taking Rope round Curves—Connection between Rope and Set of Tubs.

We have seen that what we have described as haulage direct is the system in which only one rope is used, which draws up the loaded gang to the pit bottom, the gradient from

the shaft being sufficient to cause the empty gang to run back by gravitation and draw the hauling rope along with it. This system is only applicable in the not very general circumstances of the gradient from the shaft being throughout a falling one, and at no point less than 1 in 30. If the roadways are level or irregular, sometimes falling and sometimes rising, or if at any point from the shaft the descent is not great enough for the empty tubs to run by gravitation, we want some means of hauling the empties. This we accomplish by having, in addition to the main hauling rope attached to the front end of the gang for drawing the loaded tubs, an additional rope attached to the back end of the gang, by means of which we can haul the empty tubs back over any gradient. This, which we call the tail rope system, has long held an important position in the Northern coalfield, and mining engineers in other parts of England became so interested in it that the North of England Institute in 1865 did yeoman's service to mining engineering by appointing a tail rope committee to make experiments all over the colliery districts. The result of this committee was the publication of an elaborate report in 1867, giving the results of numerous experiments with tail rope and other systems, and that report remains to this day a monument to the industry of the working members of the committee, to the ability of their engineers—namely, Mr. G. H. Wright, for a couple of months in the preparatory stage; afterwards, and to the end, Mr. Emerson Bainbridge—and the most valuable work on haulage in any language. One chief cause of the appointment of the committee was the reading of a paper by the then vigorous and now veteran colliery authority, Mr. G. C. Greenwell, who was ably assisted in the preparation of the paper by Mr. Berkeley. We take the liberty of quoting freely from that paper, and of selecting such illustrations as are necessary for clear explanation.

The particular colliery which Mr. Greenwell selected to illustrate the system was the Marley Hill Colliery in Durham. The engine was near the shaft and placed below the wagon-way. (There are some advantages, no doubt, in placing the hauling engines below the wagon-way, one being that the working road is left quite clear,

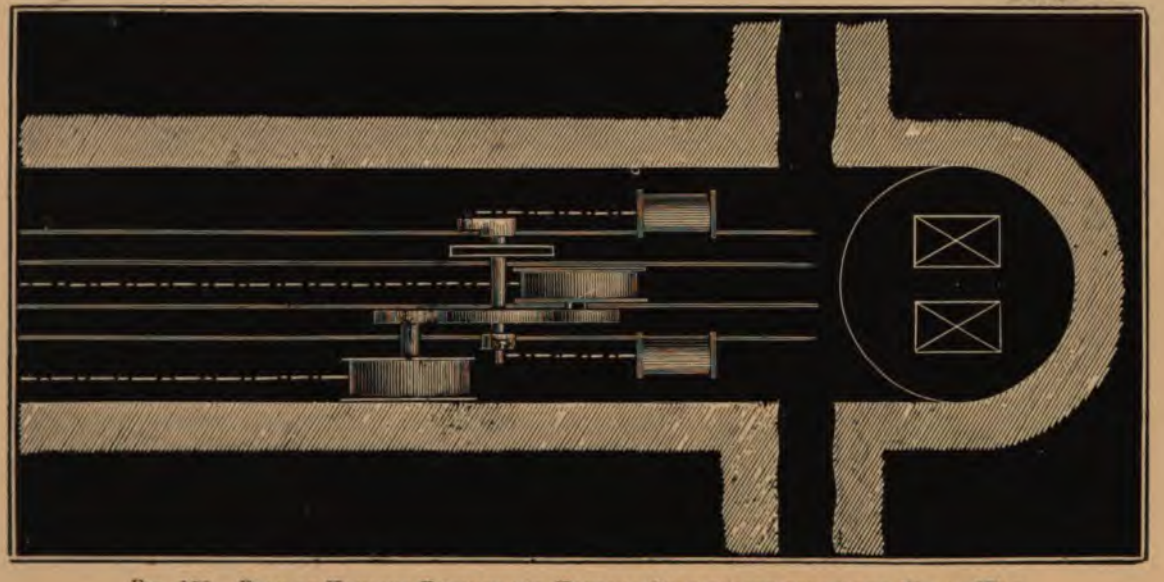


FIG. 152.—PLAN OF HAULING ENGINES AND HAULING GEAR PLACED BELOW THE WAGON WAY.



but there are probably more than counterbalancing advantages in having the engines above the wagon-way and well within sight. The writer had experience in one case where the cylinders and pipes only were placed below, and very great trouble and inconvenience resulted.) It had two horizontal cylinders 20 in. diameter each, and stroke 3 ft. 6 in. The two drums—namely, the main rope drum and the tail rope drum—were 6 ft. diameter, each being on a separate shaft connected to the engine-shaft by spur-gearing. (See fig. 152.) The length of rope required to work any plane was three times the length of the plane, for supposing the empty train of tubs to be starting from the shaft, there was the rope which, fastened to the front of the train, passes to the far end, round a sheave, and back to the drum (now in gear), draws the train to its destination, and the rope which, fastened to the back of the train, was drawn off the other drum (now out of gear), and which, together with the other rope, when the empty train has arrived at the station, was detached from it and attached to the full train waiting to be drawn out. The drum first named was then thrown out and that last named into gear, and the load drawn to the engine. Strictly speaking, either of these ropes was the tail rope, as it was attached to the tail of the train; but that which was used to bring out the full train was commonly called the main rope, and the other, which was usually of a lighter description, was called the tail rope. The brake was always kept lightly on that drum which was out of gear, so as to prevent its momentum from allowing any slack rope to run off, or any sudden check to the speed of the train, or to prevent the train where the road may have an inclination from over-running the rope which was in gear, and where this inclination was steep it was necessary to apply the brake more strongly. The main rope and the tail rope were carried upon rollers and pulleys fixed 12 yards apart, and at the far end the rope passed round a pulley 6 ft. diameter. The arrangement of which fig. 153 gives the plan, and figs. 154, 155, 156 various sections, was used to bring coal from four stations. The arrangements of the mine do not appear to have been at all unfavourable for haulage. All the branches had an inclination to the main road, which also fell to the pit

shaft. The very heaviest inclination seems to have been 1 in 33, and over a very great portion of the roadways there appears to have been practically no gradient at all, certainly no gradient worth naming to those unfortunates who constantly contend with 1 in 4, and 1 in 6, and 1 in 10.

When desired to bring coal from some station other than that from which it was brought last, the following process was gone through. Suppose that a train of full tubs has been brought from station No. 3, and the signal has been given that the next train of empties was required to be sent to station No. 1, where a full train was ready to be sent away. There was lying in the branch, from the point of divergence from the main line to the station No. 1 a rope which, having at the end a few yards of chain with large links, passes over rollers round a six-feet pulley, and back along the side of the way upon pulleys to the same point, and at this end of the rope there is a plain socket. When the empty train had been drawn to this point it was stopped; the rope fastened to the front was detached, and the branch rope was hung on by means of one of the links referred to, the remaining part of the chain, if any, being put in the first tub. About the same point that the other end of the branch rope was lying there was a joint on the tail rope by means of two sockets, which were fastened together by a common shackle and screw bolt, the bolt having a head like a bed screw; this joint was now broken, and made between the end of the tail rope next to the engine and the socket at the other end of the branch rope. The engine, being again put in motion, draws the empty set into station No. 1, and this process was repeated whenever any other station was ready to send away coals. When the socket at the end of the branch rope was not opposite to the socket in the tail rope, it was sometimes requisite to employ a winch to haul it to this point, and it was, therefore, necessary to provide a winch for this purpose. Instead of carrying the branch tail rope round the curve, it has been found more convenient to pass it under the way, and to turn it round a six-feet pulley by the side of the main line. (See fig. 157.)

The tubs, which empty weighed 5 cwt. and carried



Fig. 157.—Sho

8½ cwt., were conveyed in gangs of seventy; and fig. 158 shows the self-acting apparatus used for detaching the rope from the end of the train when drawn up to the shaft, the upper portion, A, striking against a piece of wood, lifts the pin, B, by which the shackle at the rope, or chain end, is at once disconnected from the tub.

It is near upon twenty years since this contrivance was first illustrated, and during that long period the ingenuity of colliery engineers has introduced probably hundreds of these easy-detaching or self-detaching appliances. But there is a simple effectiveness about this arrangement which entitles it to a place here.

Numerous figures were given in the paper to show the times occupied in bringing a gang of loaded tubs from the various stations and a gang of empties back again, and the result can hardly be considered satisfactory. Other figures were given to show the work done and the power expended by the engines. These are even less satisfactory. The work of haulage only shows a useful effect for the engines of 40 per cent., which could not have been accepted as a proper condition of things then, and certainly would not be so accepted now.

In making the calculations as to power expended and effect obtained, everything seems to have been taken into consideration — namely, weight of tubs and coals, and hauling rope; and friction of these, and also friction of rollers and pulleys on which the hauling ropes worked. It will have been observed that the writer of these chapters has never included in his calculations any allowance for friction of rollers and pulleys, although, no doubt, such friction exists and has to be overcome. But, on the other hand, whilst Mr. Greenwell allows a co-efficient of friction for pulleys and rope of 1-28th, and only a co-efficient for friction of tubs and coals of 1-82nd, the writer has adopted throughout in haulage a uniform co-efficient of 1-28th, which, whatever experiments may have shown to the contrary, he is quite satisfied is much nearer the mark with an average tub on an average colliery road than such a co-efficient of 1-82nd.

During the present year* careful experiments have been made upon a long system of haulage, and the dyna-

* 1884.

mometer readings have absolutely agreed with allowing a co-efficient of friction 1-28th.

And it may be assumed that at the speed to which Mr. Greenwell's paper refers—namely, seven miles an hour—a friction allowance of 1-82nd was not sufficient.

This all goes to show that a much larger useful effect was being obtained than the author of the paper thought, and this useful effect is made still greater when we come to deal with the engines.

We are told that the engines placed underground were supplied with steam from boilers stationed on the surface, and distant 200 yards from the engines.

Steam was brought in good-sized pipes, 7 in. diameter, well protected, and a very excellent contrivance—namely, a receiver of considerable dimensions—was placed close to the engines, and the result was that whilst the steam pressure at the boilers above varied from 31 lb. to 28¾ lb., the pressure at the receiver below varied from 30 lb. to 26½ lb.

This, showing a difference in steam pressure between the receiver and the boilers, distant 200 yards, never exceeding 2 lb., speaks volumes for the efficiency of well-covered pipes and steam-receivers.

But in calculating the power of the engines, it does not appear that any indicator diagrams were taken; certainly none were given. And the indicated pressure at the engines from which the power is calculated is spoken of as 29 lb. Now, seeing that the steam pressure at the boilers never exceeded 31 lb., and in the receiver sometimes fell as low as 26½ lb., it is simply impossible that the effective pressure of steam upon the pistons was anything like 29 lb. Reckoning back pressure and diminution of steam pressure, we should not be far wrong in following the good old rule that the effective pressure will be about two-thirds the boiler pressure, and this gives us about 20 lb. instead of 29.

It is easy to see from this line of argument that the engines in question were really giving a very high useful effect, and certainly nothing so low as 40 per cent.

The average daily quantity of coal dealt with was 569 tons, and the cost for labour, materials and fuel to generate steam was given at 1·6d. per ton. The machinery

could probably have dealt with considerably more in quantity, and so have materially reduced this charge, probably to little over 1d. per ton. The quantity of coal used in firing the boilers amounted to nearly 10 lb. per indicated horse-power per hour. This, although enormous if we consider the theoretic efficiency of coal, will compare very favourably with colliery engines even in the present year, and this comparatively favourable condition of things we attribute to carefully covered steam pipes and a good steam receiver.

It is a little remarkable that we always consider it necessary in conveying compressed air from the air-compressing engines above ground to the hauling and pumping engines below ground to have a receiver of considerable dimensions in the mine, but we do not act as if we thought it equally essential to provide a similar appliance when conveying steam from boilers on the surface. But the circumstances are practically the same. There is, perhaps, not much, if any, diminution in the loss of power on the way, because in any case there is the same distance to travel, and consequently the same amount of friction; but we get a higher efficiency in the hauling or pumping engines, for several reasons. The water which accompanies compressed air, and which arises from condensation when steam is used, deposits in the receiver, and can be drawn off or even expel itself automatically, therefore does not get into the working cylinder to bring down useful effect; and as the steam or air is not wire-drawn, there is always a good supply of full pressure, even when the engines are running at a high speed. The writer is so vigorous an advocate for receivers that even when the boilers and engines are comparatively close together he believes in having large steam capacity either in the boiler itself, as in a good Lancashire boiler, where there is half as much room for steam as for water, or, failing this, by having a large steam dome. The objection to this latter used to be that the connection with the boiler, necessitating a large cutting away of the shell, had a seriously weakening effect. This is easily remedied or prevented by not cutting away the shell, but merely perforating the plate, thus preserving the strength, and making it more difficult for water to rise along with the

steam; also a good receiver quite close in to the engines and thus practically have the engines which use the steam and the boilers which generate it in close proximity. In every case, whether using compressed air or steam, receivers will have a beneficial influence in regular working and high useful effect. A comparison was made as between the actual cost with the hauling machinery, including labour and materials and coals—which for one year amounted to £1,500—and the previous cost of horses, which had amounted to nearly double. To show the still further advantage of the mechanical arrangement, it was pointed out that whilst the horses had been worked to the full extent of their power, the machinery was capable, over and above what it was then doing, of the work of an additional fifty horses. The comparison was instructive then, and is interesting even now; but in our day no intelligent person (and none but highly intelligent should be allowed any management in mines) would think of using horses where mechanical power is at all possible. This was considered a high-class example of tail-rope haulage twenty years ago, and may be accepted as a fair example even yet, and whilst naturally having the support of engineers from its own special district, the North, called forth very high and almost unanimous eulogiums from Lancashire and Cheshire engineers; in the former county the paper was read and discussion taken. Some few there were who spoke in favour of endless haulage by rope or chain, but they were in the minority then, even in their own districts, and tail rope reigned supreme.

The system we have just been dealing with is not perhaps the tail rope in its simplest form, there being so many branches to work. The tail-rope arrangement in its most elementary form is where there is only one road and one place to travel from. The inclination is irregular, or else not sufficient for tubs to descend by gravitation. The hauling rope attaches to the front end of the loaded gang; the tail rope, which passes round a wheel at the far end, attaches to the back end of the loaded gang, and away it goes to the pit shaft. Then on the return journey on the same road, the tail-rope attaches to the front end of the returning empty gang and the hauling rope to the back end, and the return journey is made. The result of

Mr. Greenwell's paper (which we trust, after a lapse of nearly a generation has a general interest, so far as references to it have gone, to many of our readers) and the interesting discussion that followed resulted in the appointment in August, 1865, of the committee to consider the relative merits of the tail rope and the endless chain.

That committee comprised a large number of our principal mining engineers, representing the chief mining counties. As is customary, especially upon large committees, most of those gentlemen were merely ornamental members, except in one important respect—namely, in affording facilities at their various collieries for making experiments. The members of this committee to whom the mining world are most indebted were the hon. secretary, Mr. William Cochrane, and the acting engineer for the first two months, Mr. G. H. Wright, and afterwards and chiefly Mr. Emerson Bainbridge.

We shall endeavour to show our appreciation of their very excellent service by making use freely of their North of England report on haulage, extracting some information first of all from that portion dealing with tail-rope appliances. Every work on colliery engineering, published in whatever language during the present generation, has, by referring to and largely quoting from it, admitted its pre-eminence as a treatise reliable and exhaustive on haulage.

The most elaborate tail-rope arrangement dealt with by the North of England Committee was at the North Hetton Colliery, famous in many respects, and not least in its identification with the name and family of Wood. Nicholas Wood will ever be remembered as being a leader in every mining movement for near upon half-a-century, and also as having been a contemporary and intimate friend of George Stephenson. There were two main wagon roads lying at right angles to each other, No. 1 being driven east and No. 2 north. There were two cylinders, each 12 in. diameter and 24 in. stroke, four drums, each 4 ft. diameter, pulleys for supporting the rope 7 yards apart, and steam conveyed from boilers stationed on the surface. The engine was geared 3 to 1, and made an average speed of 180 strokes per minute, which, representing 720 piston feet per minute, was quite fast enough,

The engines and drums were placed below the wagon way. In No. 1 plane all the ways had a rise to the shaft, none of the branches were of very great length, the heaviest gradient was 1 in 10½; there were twenty-one tubs in each set, and the speed of the set was ten miles an hour. In No. 2 plane all the ways fell to the shaft, the heaviest gradient was 1 in 15; there were thirty-five tubs in each set, and the speed was again ten miles an hour. There were, of course, two drums to work each plane. The shackle joints for connecting one rope to another were as shown on fig. 159. All the large pulleys at the curves and at the far end were the same diameter as the drums, viz., 4 ft. The ropes were connected to the set by means of the link shown in fig. 160. The horse-power exerted in haulage at this colliery was 100, being the full extent of the capabilities of the engines. We have not considered it absolutely necessary to reproduce the drawings of this and the other tail-rope arrangements. The one taken from Mr. Greenwell's paper may be taken as generally showing the principle attaching to them all. The interesting features at Hetton seem to have been the good speed attained by the engines and the gang and the great care exercised with the ropes by having a plentiful supply of supporting rollers, and making the large pulleys at the curves to agree in size with the hauling drums.

At Seaham Colliery the engine plane was nearly 3,000 yards long—the average gradient being a rise towards the shaft of 1 in 64, being virtually level, and there were two stations by the side of the main wagon-way from which coals were led. The engine was horizontal, having two cylinders, each 18 in. diameter and 3 ft. stroke, with two drums each 6 ft. diameter. Steam was obtained from boilers fixed underground, and the pulleys upon which the ropes ran were placed eight yards apart, and the daily output in twelve hours was 522 tons.

Some very interesting and valuable experiments were made with the steam engine indicator, showing that to drive the engine alone at a speed of 48, 68, and 84 strokes per minute the horse-power exerted was 11·1, 13·3, and 20·2. To drive the ropes without load at the same speed the horse-power exerted was 30·6, 42·7, and 65·1. The general result of these experiments was that bringing a



FIG. 159.—SHACKLE JOINT FOR CONNECTING ROPES IN TAIL ROPE HAULAGE.

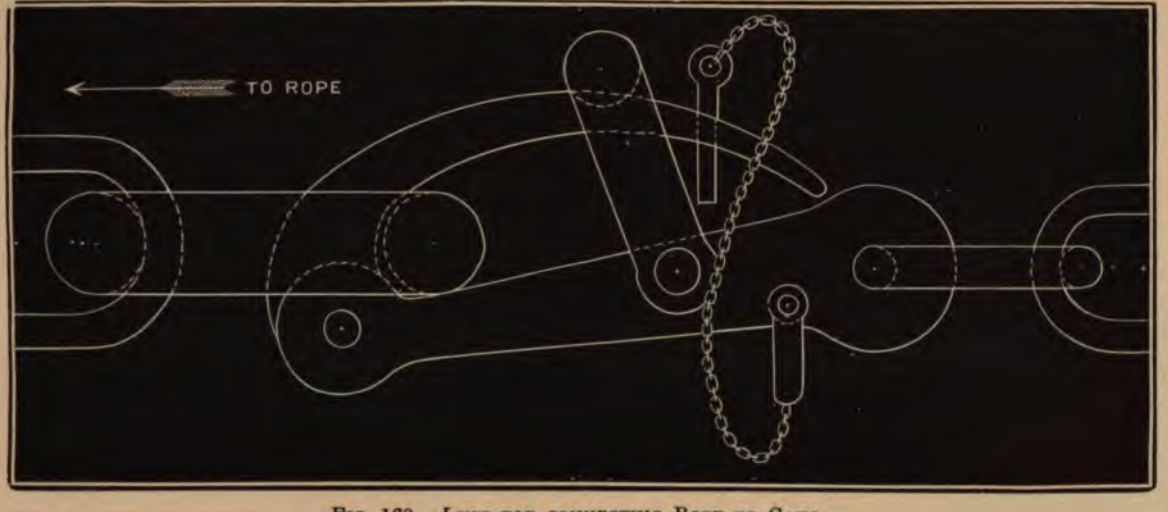


FIG. 160.—LINK FOR CONNECTING ROPE TO GANG.

[*To face page 242.*]

full gang of sixty tubs out, up an average gradient of 1 in 64, at an average speed of twelve strokes per minute, 86·1 horse-power were exerted, representing 46 per cent. for the set, 40 per cent. for the ropes, and 14 per cent. for the engines, so that more than half the work was required to give motion to the engines and the ropes. To show only 14 per cent. of the indicated horse-power absorbed by the engines will compare favourably with the best examples of modern haulage.

Experiments were also made with the dynamometer, but these are pronounced unsatisfactory.

At Seaton Delaval the engine-plane was a little over 2,000 yards long, and nearly level, having an average gradient of 1 in 643 falling to the shaft. (We look upon gradients somewhat differently in different districts. In the north, 1 in 643 is spoken of as nearly level; in other counties we should consider the 1 in 64 at Seaham practically level.) All the coals were led from the far end, there being no intermediate stations. This gives an example of tail-rope arrangement almost in its primitive simplicity. The engine was horizontal, with one cylinder 28 in. diameter and 6 ft. stroke, and the two drums, each 6 ft. diameter, on different shafts. The engine did double duty, hauling coals and pumping water into the boiler during the day, and pumping water into the boilers at night. The steam was obtained under the most favourable circumstances—namely, from boilers fixed underground quite close to the engine. The daily output has varied from 1,300 tons in the best days to 500 tons in its more advanced age. The pulleys for supporting the rope were placed at distances of eight yards, and the number of tubs in a gang was sixty.

Experiments with the indicator showed, in an average expenditure of 130·83 horse-power when bringing a full gang out at a speed of thirty-seven strokes per minute, 13 per cent. for the engine, 72 per cent. for the ropes, and 15 per cent. for the gang, so that nearly six-sevenths of the power exerted was needed to give motion to the engine and the ropes, which cannot at all be considered good practice. There must have been something wrong somewhere when nearly as much power was expended keeping the engine in motion as upon the loaded gang. And the

fault was certainly not in the amount of power—namely, 13 per cent. absorbed by the engine, because we have already spoken of even 14 per cent. being fairly good. The ropes must have been exceedingly heavy and, further, must have generated excessive friction. A useful effect not exceeding 15 per cent. in a North of England hauling arrangement is something startling.

At Harradon Colliery two branches were worked, and the average gradient was in favour of the full tubs. The engine plane was nearly 2,000 yards long to the north-way terminus, and about the same distance to the west-way terminus. The daily output was 650 tons. The hauling engine was vertical, with two cylinders each 20 in. diameter and 3 ft. stroke, the drums 5 ft. diameter, and the spur gearing such that the drums made one-third more revolutions than the engines. Steam was obtained from boilers on the surface, and the pulleys on which the ropes worked were placed 9 yards apart. The main pulleys for the tail rope to pass round were 6 ft. and 8 ft. diameter.

The indicator experiments come out much more satisfactorily here—namely, in running at forty-nine strokes per minute, 149·39-horse power was exerted, divided as follows—17 per cent. for the engine, 37 per cent. for the ropes, and 46 per cent. for the loaded gang. This arrangement seems almost to have been on first motion, the proportion being 3 to 4; the drums were a fair size, and the large pulleys excellent in point of dimensions and must have rendered material assistance in attaining the gratifying useful effect of 46 per cent. The proportion of work absorbed by the engines in the foregoing three examples comes out in almost striking uniformity.

At Murton Colliery the daily quantity varied from 520 to 430 tons, and there are no branches, the length of plane the coals are led over from the south-east or far off landing being 2,770 yards, and 1,978 yards from the intermediate station, the distance from the engine to the tail wheel being 2,816 yards. The hauling engine is a double 18 in. cylinder horizontal engine with 2 ft. stroke. The drums were each 5 ft. diameter, and on the second motion, the revolutions of the pinion wheel to the spur wheel driving

the main drum being as 2·387 and as 1·581 to 1 to the spur wheel driving the tail drum. Steam was obtained not under the most favourable conditions, viz., from boilers fixed underground, but 300 yards from the engine. The ropes were supported upon pulleys placed 12 yards apart, and forty-eight tubs formed a gang.

One special feature in this hauling arrangement was that a three cranked single action force pump was worked by the tail rope by means of three friction wheels, and a similar pump was worked by the tail wheel. (When water has to be dealt with at a considerable distance in the mine, it is much better to make use of a hauling rope which passes the place, provided this can be done—which is possible with care—without damaging the rope, than to have the expense and serious loss of efficiency inevitable with the conveyance of steam perhaps a mile. We make no reference to difficulties attending the exhaust so far away from the pit bottom, because it has been shown in the articles on pumping that exhaust need not be an insuperable obstacle when we have plenty of water). The indicator experiments showed that with the full gang coming out at a speed of forty-eight strokes per minute, 83·09-horse power was being exerted, of which only 7 per cent. was upon the engine, 33 per cent. upon the ropes, and consequently leaving the good balance of 60 per cent. upon the loaded gang. This very high useful effect is certainly gratifying and by no means impossible, therefore the figures may be accepted. But the low percentage of 7 absorbed by the engine is almost too good to be true. We are very liable, especially in these days of wonderful improvements in machinery, to forget that however well our engines may be made, they generate some friction and absorb some of their own work to overcome their own resistances. The indicator diagrams from a steam engine do not show the power which the engine is performing or even capable of performing upon something with which it is connected. The diagrams show the power which is being exerted upon the pistons of the engine. It is a very good engine even now which gives a modulus of 90 per cent., and here we have an example a generation old, showing 93 per cent. The Murton authorities are to be congratulated on the especial excellence.

Experiments were made at this colliery to find the friction of tubs. The size of the tub wheel is given 14 in. diameter, but not the size of the axle, and the co-efficient of friction arrived at is $\frac{1}{56\cdot2}$ for loaded tubs, and $\frac{1}{46\cdot5}$ for empty tubs. We simply state the fact, again asserting that the reasonable co-efficient for an average tub in an average colliery is not 1-80, or 1-56, or 1-46, but 1-28, namely, 4 lb. per cwt.

The following figures should also be given :—

Cost of leading coals per ton per mile up an average gradient of 1 in 83, the average distance being 1·414 miles, and the average quantity led being 407 tons per day, 2·172d. at Murton.

Cost of leading coals per ton per mile down an average gradient of 1 in 83, the average distance led being 1·002 miles, and the average quantity led being 586 tons per day, 1·515d. at Harradon.

Cost of leading coals per ton per mile down an average gradient of 1 in 643, the average distance led being 1·170 miles, and the average quantity led being 389 tons per day, 1·882d. at Seaton Delaval.

Cost of leading coals per ton per mile, up an average gradient of 1 in 64, an average distance of 1·261 miles, the average quantity led being 522 tons per day, 1·948d. at Seaham.

In summarising their report, the North of England Committee, as regards the tail rope system said, that one of its leading features was that it could be applied under almost any condition of wagon way, the crookedness of the way, irregularity of gradient, and numerous stations and branches, forming no obstacle to its effective working. (We shall probably find, in the progress of these articles, that the tail-rope is not peculiar, even in this). On a single road the tail-rope would be generally applied when the gradient of the wagon-way is not sufficient to cause the empty tubs to draw a single rope after them, or when the falling gradient to the shaft is not sufficient to make the loaded tubs self act, or when the full tubs coming out will not pull the single tail-rope after them. A single tail-rope—that is, a tail-rope working without a main rope—will operate where the engine-plane rises from the shaft, and the rope passing round a pulley at the far end

of the plane will draw the empty tubs up the bank, the loaded gang being usually braked down. This arrangement can be adopted when the gradient is hardly sufficient for a loaded descending gang to pull up an empty ascending gang. The tail rope is a quick and intermittent system of haulage, and has consequently to contend with difficulties of which slower and continuous systems know nothing. A high speed, exceeding in some cases ten miles an hour, necessitates better rolling stock, more expensive roads, and stronger ropes and chains. There is also more friction, resulting in a less useful effect, and a mishap, such as a gang leaving the rails, causes great damage. The work being intermittent the machinery is idle a considerable portion of each day, that is adding all the intervals of rest, and consequently more powerful machinery has to be used than if the work was uniform and continuous, and the engines working all through the day.

Then the number of times which the machinery has to be started and stopped, and the suddenness with which a high speed has to be attained, is considerably more injurious, and causes more wear and tear upon all the appliances than doing the work.

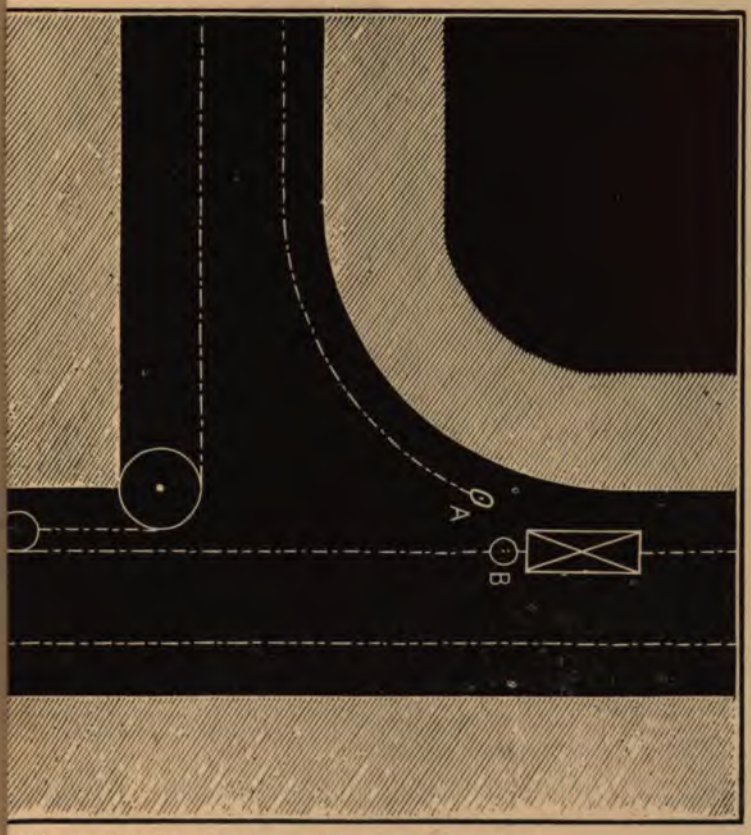
The usual arrangements for working the tail-rope system consist of a pair of engines with two drums either on the engine shaft or worked on the second motion, in which case the drums can either be on different shafts, and be put in and out of gear by shifting carriages, or they may be put on the same shaft, clutch gear, or, what is much better, friction gear—being then used for connecting them with the engine. One important matter, well worth careful consideration, is the needful arrangements for enabling the drums to run loosely upon the shafts. This, of course, and especially with large and therefore comparatively heavy, drums, will occasion a good deal of wear. The drum rings should be bushed with some material which will wear well and generate a minimum amount of friction; the shaft, or shafts, should be well turned and the bushes nicely bored, and when worn to any extent should be removed and new bushes inserted. If the drums have actually to run loose upon their shafts a perfect arrangement would seem to be not only to bush

the drums, but also provide for some wear which is inevitable upon the shafts themselves. This could be effected by having the portions of the shafts on which the drums worked made larger in diameter, and then if they displayed a tendency at any time to wear slightly oval we might make a thoroughly good job again by taking out the shafts and re-turning them in the lathe. One drum is used for the main rope and the other for the tail rope. At the far end of the main road and of each of the branches from the main road there is a pulley round which a tail rope passes, both ends of which, when used on the branches, are brought to a station on the main line; when only one way is worked one end of the tail rope is brought to the station, whilst the other is attached to the tail drum. In taking a set of tubs, which may number from thirty to a hundred in, the tail-rope drum is connected to the engine, and in coming out, the main-rope drum. In going both in and out the brake is gently applied to the loose drum to prevent the dragged rope from becoming too slack. When two wagon-ways have to be worked in opposite directions from the engine, four drums are generally used, there being then a main and tail rope for each way.

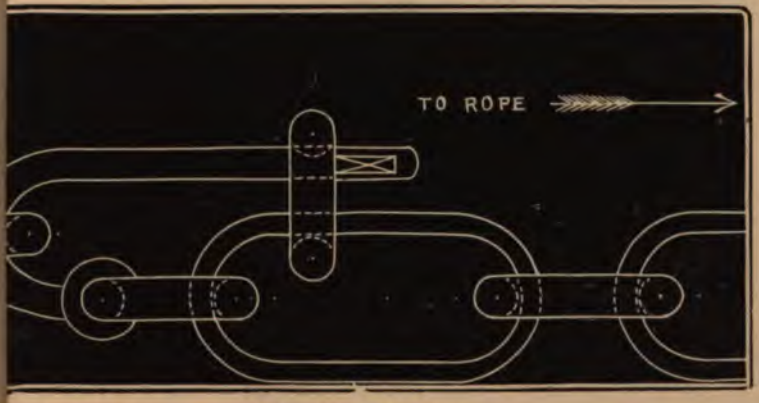
It is found by experience that curves can be worked by the tail-rope system at any angle, and at a comparatively small radius. With a curve twenty-two yards radius gangs pass round safely at a speed of ten miles an hour.

In working branches by the tail-rope system there are three methods of attaching the branch-rope ends to the main rope. (See figs. 161, 162, and 163, which are marked respectively as methods A, B, and C.)

In figs. 161 and 162 the ropes are changed when the set of tubs is near to the branch end, and in fig. 163 when the set is at the shaft. In fig. 161 a wheel is fixed near the roof or under the rails round which one end of the branch rope passes. When the incoming set has to go into the branch the rope-end, C, replaces D on the fore end of the set, and the end, E, replaces F on the tail rope. In fig. 162 the tail rope always remains entire; the end, A, replaces B, and the end, B, of the rope is brought a little further by the engine, and is then attached to N.



"B" of Connecting Branch Rope to Main Rope.



Knock-off Link used in Tail Rope Haulage.

[*To face page* 248.]





This method of attaching the ropes can be worked without a winch, which is generally found necessary with fig. 161. In changing the ropes by method shown in fig. 163 a different course is pursued. When a set is taken out from any station to the shaft the boy at one end of the branch ends changes the ropes whilst the ropes at the shaft are being attached to the empty set. The position of the ropes is so arranged that when the set reaches the shaft the shackles on the main and tail ropes are just opposite to each other at each branch end, as shown on fig. 163, when the rope ends, X X, are replaced by Y Y. This plan is more expeditious than either figs. 161 or 162, because no time is lost in changing the ropes, as they are generally ready at the branch end before the set is ready at the shaft; but with the other methods another stoppage, in addition to the time required to change the ropes at the shaft, is necessary.

These figures also show different methods of taking the ropes round curves. In fig. 161 the curve has a larger radius, and the tail rope is taken round a single pulley, and along a narrow place, a pillar of coal supporting the roof between it and the curve. The curve in fig. 162 is less in radius, and no pillar is left. In fig. 163, which is generally adopted on very short curves, instead of taking the tail rope round a single pulley, both ropes are taken round the curves by a number of pulleys.

The connection between the rope and the set of tubs is usually made by a knock-off link, as already shown on fig. 159, or now shown on fig. 164, a slight blow to which detaches the rope from the set.

CHAPTER XXII.

HAULAGE.—THE ENDLESS CHAIN SYSTEM.

No one System of Haulage generally adaptable — The Endless Chain eminently suitable at Burnley—Used for Surface and Underground Haulage—The Endless Chain automatically attaches to the Tubs—Receives comparatively no Injury by Exposure to Weather—Arrangements at Rowley Colliery—Endless Chain for Winding—Disadvantages of the System—Haulage Chain passing from Surface to Underground—Limit to the Effectiveness of the Arrangement—Impracticability with Pits of considerable Depth—Engines and Boilers below Ground—Description of Engine—Connection of Boilers with Upcast Shaft—Advantages and Dangers of Boilers placed Underground—How Power is transmitted from Engines to Chains—Number of Hauling Chains—Appliances for throwing any Chain in or out of Gear—Defectiveness of ordinary Forms of Clutch Gear—Construction of Driving Pulleys—Object of the "Feet" placed upon the Pulleys—Guide Pulleys—Obtaining needful Friction for the Driving Chains—Weight and Safe Load of Chains—Stretching of Chains—Cause of Wear in Chains and how prevented—Position of Tubs—How Branch Chains are worked—Chains working upon Level Roads—Chains working to the Dip—Chains working to the Rise—Construction of Tubs at Burnley—Attachment of Chain to Tubs—Speed of Endless Chains—The Hargreaves Collieries at Burnley—Mr. R. Handsley —Mr. H. Waddington—Length of Endless Chain in Use—The North of England Committee on Endless Chain Haulage—Economy as regards Roads—Self-acting Curve in Endless Chain Haulage—Hapton Valley Colliery—Description of Gearing and Arrangement of Tubs—Experiments as to Power—Cost of leading — Gannow Colliery — Description of Gearing — Cost of leading — Rowley Colliery — Cost of leading — Surface Endless Chain at Burnley—Cost of leading—Surface Endless Chain at Clifton Hall—Absence of Forks from Tubs—Disadvantages of the Arrangement—The South Wales Endless Chain—Haulage by Endless Chain at Coltness—Description of Engines and Gearing and Roadway — The Work upon the Engines—Experiments with Dynamometer—Size and Weight and Strength of Chain — Mishaps in Working — Arrangements for stopping the Tubs when Chain breaks — Excellence of the Coltness Appliances—Mr. R. Russell—Endless Chain in the North of England—Arrangements for passing round Curves.

It is not possible to have one of the many systems of haulage underground to give uniformly good results in

all mines, because special conditions arise which have to be dealt with in a special manner, and it oftener happens than not that the engineers of any one district adopt those appliances for haulage which answer best for their particular case.

In Burnley the endless chain reigns supreme, is eminently adapted to the natural peculiarities of the district, is brought into use in almost every possible way for all possible kinds of work, and it is scarcely possible to see it in operation in so many ways without congratulating those who have so perfected the system, and without becoming to some extent enamoured of it. The country itself is of a very uphill and down-dale character, not economical in many parts for carting operations, and not well adaptable in every case for railway formation. An endless chain capable in itself, unlike ropes, of being exposed without injury to all kinds of weather (and affording an easy, in fact practically automatic attachment to the tub, without the slightest injury or undue strain to the chain, as would be unavoidable with a rope), and enabling an arrangement whereby hills could be mounted and valleys descended with practically as much ease and almost economy as working upon level roads, was a system which long ago was seen to be the most effective for such a district, and those who introduced it did well for themselves and well for their posterity.

In Burnley we have endless chains everywhere, conveying coals to the canal and the railway and the town, to boilers, to coke ovens, to screens, endless chains actually raising the coal from the shaft-bottom to the surface, and bringing it from all parts of the mine. In one case, namely, Rowley, the endless chain seems to do everything, from the time the coals are put into the tub till discharged into the wagon or cart or boat. The chain hauls them underground and well-nigh puts them into the cage, winds them up the pit and almost does the banking; finally gets hold of them again and carries them away a short distance, or a mile or two, as circumstances require, to the point of loading. There are few more singular or interesting sights than to see in the distance loaded tubs quietly ascending a hill, and empty tubs as cautiously descending into a valley as if they were living beings. It was a happy

idea to have for frontispiece to the Report on Haulage, already more than once referred to in these pages, an excellent illustration of the surface endless chain arrangements at the famous Rowley Colliery, than which there is nothing even yet more interesting in the extensive coalfield of Burnley.

It is not proposed here to deal with haulage upon the surface, because in principle it does not differ from haulage underground, nor with endless chains for winding in shafts. That these are economical is unquestionable, and for shallow shafts have done good work, but they are not available for raising and lowering men, and are liable now and then to have a mishap, the very large number of parts making it almost impossible to discover every defect, and if one place gives way the whole business goes down the shaft, making a fearful mess and blocking the place. Even for shallow pits the total weight of links, &c., in the shaft is enormous and for our modern pits of 600 and 800 yards would be something to think about. The one only argument needed against these endless chains for winding is that even in the endless chain country they are dying out, they are not adopted at new places, and in a few more years will have become a thing of the past. When in good working order such an arrangement gives a very high useful effect, on account of the continuous working, which naturally is productive of economy when contrasted with the extravagant but inevitable intermittent operations of our modern winding plant.

The arrangement also of having the hauling engine upon the surface, and passing the chain down the pit to effect the haulage underground is not one that the writer cares to recommend. For shallow pits it may answer, and does answer well, but we want, if possible, appliances little or not at all affected by the depth, because deep mining must for many years play a more and more important part amongst us. We shall probably have to speak favourably of hauling engines placed upon the surface and having ropes in the shaft working ropes underground, but the circumstances are not the same. Even with ropes we ultimately reach a depth of pit at which the weight of the rope will exceed its safe load, and as we shall have occasion to remark that to do similar work



is probably four times as heavy as a rope of high
we see at once that chains become impracticable
very moderate depths.

Burnley we have excellent examples of endless
aulage with the engine and boiler both fixed under-
; and for underground haulage the chain should
d to come down the pit.

. 165 shows the engine in elevation, and it seems a
ype; the gearing is below, and the whole of the
is within view of the engineman, and occupies
ttle space; and such an engine with cylinder only
diameter and stroke 2 ft. taking steam from a
never exceeding 30 lb. in pressure and often as low
b. does all the haulage of an extensive mine com-
many miles of chain. It is only fair to say that
cumstances of the mine are favourable, there being
t average fall to the pit shaft.

. 166 shows plan of the engine and boilers, which
arranged in connection with the upcast shaft that
iler flues deliver into a chimney built within
cast shaft and carried up some 20 or 30 yards,
ea being to prevent the heat acting injuriously
he coal surrounding the shaft. The writer is
favour of having steam boilers underground;
higher amount of work with a given amount of
obtainable when engines and boilers are under-
and close together is quite true, but some amount
attends steam boilers in the mine, and only in
xceptional cases can they be recommended. In
ecial case the boilers are quite near the pit shaft,
e flues kept quite free from contact with anything
o take fire.

haulage is performed by three principal chains
from the engine by means of shafts and pinions
eels and bevel gearing, as shown in fig. 167. Each
al chain has its separate pulley and upright shaft
vel gearing at the top, and catch box to put in or
gear, see fig. 163, because whilst all the chains may
ork at one time there are other periods when one
r of them, even in the most uniformly worked
es, is doing nothing, or at any rate less than the

These catch box arrangements, whilst equal to such appliances in general use, are not efficient. They necessitate the stoppage or nearly so of the entire system every time a chain wants throwing into gear, or else there is a risk of breaking something. There is certainly an arrangement intended in the event of a block from tubs getting off the road or other cause to prevent undue strain coming upon the engine. Clamms grip a turned portion of the driving pulley tightly enough not to be affected by any ordinary strain arising from ordinary work, and any undue strain will cause them to slip. This is well enough, so far as it goes, but what we want is to avoid the necessity of stopping or slackening to put it in gear. To do so disarranges work more or less, and causes some delay, and as men are sometimes a little neglectful the not doing this brings about a breakage, and perhaps a stoppage of at least a part of the mine for several hours, perhaps a day is lost. What we want is a clutch box arrangement doing all that the best of the old ones do, and enabling the machinery to be thrown in or out of gear, at whatever speed, without having to check and with a minimum shock. We hope during these articles on haulage to illustrate and describe an appliance which accomplishes this.*

These three principal chains have their driving wheels placed convenient to the shaft to allow easy delivery into the cage, and the needful gearing connecting them with each other and with the engine is carried upon neat and substantial wrought-iron girders. Such an arrangement it appears to the writer is better than putting such gearing underground; it is well out of the way, causing no inconvenience, and can easily be got at for oiling and inspection. Each catch box is worked by a separate handle at the wheel itself, which is perhaps as good a plan as any for preventing mistakes, although there need be no difficulty in putting them all together, say in the engine-house under the eye of one man, the engineman.

The pulley round which the chain coils to obtain the needed power is ordinary in its framework, but has round its circumference a ring of boiler plate the breadth of which depends upon the work to be done. This ring is

* *See* Endless Rope Haulage at Clifton.



Fig. 169.—Foot for taking Wear and giving Chain a better Grip on Hauling Pulley.



Fig. 170.—Front Elevation of Main Hauling Pulley for Endless Chain and Small Guide Pulleys.



Fig. 171.—Side Elevation of Main Hauling Pulley for Endless Chain and Small Guide Pulley.

[*To face page* 255.]

secured to the framework of the pulley and has in turn secured to its circumference a number of feet, as shown in fig. 169. These "feet" are of wrought iron, with steeled faces, and upon these the chain works and upon nothing else—the pulley being merely a support and communicating circumferential motion to them. They are shaped to answer for one or two or three laps, as the case may be, and their twofold object is to prevent the chain dropping off and also to prevent its climbing. We may fairly claim for these "feet" that they do a little more even than this. The pulley itself does not get worn at all, because really the "feet" are so placed round the circumference that the chain bears only upon them. They also prevent slipping, which, whilst almost inevitable on a smooth circular surface, is not nearly so likely upon what becomes practically a many-sided polygon.

To guide the chain correctly upon these feet a small vertical pulley is fixed at the entrance of the driving horizontal pulley, as shown in figs. 170 and 171. The chain receives a sufficient amount of friction by being coiled a sufficient number of times round the pulley, and in the particular case that we are describing, is made of $\frac{11}{16}$ iron, weighing about $5\frac{1}{2}$ lb. per foot, and having a safe working strain of 5 tons or thereabouts. This chain, when first set to work, stretches considerably, which will be well understood from the fact that in some endless chains there will be very many thousand links. As much as 6 ft. of slack has to be removed at once to counteract this, and afterwards the stretching is so much reduced that the removal of a few links makes matters right. A stretching arrangement might do instead of this, which could be tightened up from time to time, but by the method just named there is a fixed pulley at each end, and the plan answers well.

An endless chain made of good material (and whoever uses bad material in a mine should have his Certificate of Competency cancelled) with proper care lasts almost for ever, because as the little wear it experiences goes on it can be changed to lighter and lighter work. The great point for enabling a chain to wear a long time seems to be keeping it off the floor. The safe strength is nearly always so much greater than the load that real work does

it no harm. What does cause some wear is passing round the pulleys, and what proves ruinous is allowing it to rest upon the floor. Long channels in the floor of a mine made by the chain are as costly to mineowners as driving tunnels, and in the majority of cases are preventible.

Tubs should be placed at least near enough to each other to keep the chain up, and under ordinary circumstances this will not be difficult to accomplish. Indeed if not accomplished two results inevitably arise, the enormous friction adds enormously to the work upon the engine, and the wear and tear adds seriously to the cost of chain.

So far we have dealt with what we have called principal chains driven direct from the engine and extending a mile, or more or less as the case may be, and at the far end simply passing round an ordinary guide pulley. From this far end we may want to go off at some angle with another chain as shown in fig. 172, and if so we simply have a double pulley arrangement for communicating the needful power to the other chain. And this second pulley will be supplied with a catch box arrangement in case the additional chain shall not be in constant work.

But we may want a branch chain at some intermediate point, as shown in fig. 173, and there are two ways of accomplishing this. We might fix a double pulley arrangement, and passing the main chain round one pulley, pass on whilst the branch chain took its power from the second pulley. A better way is to have three chains and three pulleys connected by gearing, and so having nothing in the way but a clear landing place for tubs. (See fig. 174.)

It will be sufficiently clear from all this that there need be no difficulty in arranging branch chains from the main chains at almost any point. And in some cases these branch chains can either be self-acting independently of the main system by reason of working a rise, or they can be connected to the main system, and instead of requiring assistance, actually be able to give some.

There are several ways in which we might consider endless chain systems. First, where they are perfectly level throughout. This will hardly occur in practice, but in such a case the only work upon the engine would be



FIGS. 175 AND 176.—ELEVATIONS OF IRON TUB FOR ENDLESS CHAIN HAULAGE.

[*To face page* 256.]

friction. Second, we might have chains all working to the dip, or level and rise and dip with a balance to the dip; in such a case we have upon the engine the friction and so much work for drawing the coals up a certain height. Thirdly, we might have all our chains working to the rise, or such that there would be a balance to the rise, and in such a case the system would either be self-acting, or at any rate the engine would be aided.

We now come to the simple, but very essential part of the arrangement—namely, the tub in which the coal is conveyed. Wooden tubs, so prevalent in many parts of England, are not popular at Burnley, and for the endless chain an iron tub does seem more appropriate. These iron tubs are shown in figs. 175 and 176, and certainly appear substantial constructions. They are neatly and cheaply made, will not weigh more nor cost more to carry the same load than a wooden one, will carry a somewhat greater load for the same bulk in themselves, and at least stand as much wear and tear. The wheels measure some 10 in. in diameter, which will mean nearly a foot across the flanges. They are bored and the axles are turned, and there seems no very good reason why tub axles should not always be carefully turned, and pedestals and also wheels when running loose, neatly bored. The lessening a load upon the hauling engine depends upon the largeness of the wheels and smallness of the axles, both of which to a great extent are regulated by circumstances which we cannot control, but the friction of the wheel upon the axle and the axle on the pedestal also has an important influence, and the turning of axles and boring of wheels and pedestals diverts that influence in the right direction.

The attachment of the chain to the tub is very simple, the chain lies upon it, and its weight upon a level road or on moderate inclines would be sufficient. But to make the arrangement more effective and capable of working upon any incline, the wrought-iron band which goes round the tub projects up at one end, and in this projection there is a groove measuring about 1 in. wide and somewhat deeper. Into this groove the chain adapts itself without the slightest difficulty, and all goes well. The tub at the entrance to a chain receives a little impetus

by hand or otherwise sufficient to take it under the chain which then lies upon it, and at the delivery end the chain rises slightly and so liberates the tub.

As regards the speed of these endless chains it may be anything practically from one mile an hour to four miles, and that is regulated by the amount of work to be done, but probably the average speed will not exceed two miles an hour, and as endless systems of haulage are essentially slow working, and owe their success to their regularity and slowness, it is not desirable to have a speed much exceeding two miles an hour.

The foregoing presents a fair idea of almost a model endless chain haulage arrangement in the Burnley district, and the description may almost conclude with a somewhat similar remark to that which commenced it. The endless chain is scarcely known in some colliery districts, and not much approved in some others, and there is no intention of urging its universal adoption. Engineers in the various districts have always been found able and willing to adopt that system of haulage which answers their special requirements best. The endless chain is evidently superior to any other kind of haulage for the Burnley coalfield, and in no part of England, we might say of the world, can it be seen to greater advantage. The extent of its application will be judged from the fact that one firm alone has at work above ground and below nearly one hundred miles. This firm, namely, the executors of Colonel Hargreaves, by their agent, Mr. R. Handsley, and his manager Mr. H. Waddington, afforded the writer every possible facility for seeing their hauling appliances at work, and for obtaining all needful information. The success which has attended and still attends the working of these extensive collieries is owing, not more to the valuable mines under their control than it is to the skill of the officials responsible for their management.

The North of England Committee's report, in referring to endless chain haulage, says that a double line of tramway is always requisite—one line being used for the full and the other for the empty tubs. The speed at which the endless chain works varies from one to four miles an hour. The tubs are put on singly and at distances apart varying from 10 to 40 yards. The tubs are attached to

the chain by means of a fork, which forms one piece with the strap encircling the upper part of the tub. The end of the tub on which the fork is placed is made to go last in starting up hill, but in going down hill is placed first. This fork arrangement, forming part of the tub, is so at Burnley and elsewhere, where the tubs are loaded little if any above the level of the top of the tub. But at Coltness, where we have an excellent endless chain haulage, hereafter to be described, the coals stand so high above the tubs that this arrangement would scarcely answer, and in its stead we have removable forks fitting into pockets in the tubs, and these forks enable the chain to stand so far above the tub as to miss the coals. Very little care, comparatively, is needed in laying the wagon-way, in consequence of the low speed at which the tubs travel. Formerly the endless chain system was only considered adaptable to straight lines, and only used in that way, but attempts, with considerable success, have been made to take the chain round a curve, and fig. 177 gives the plan, and fig. 178 the elevation of one such arrangement. The particular angle shown is one of 90 degs., but the same arrangement would do for a larger angle or for a less. At the angle a pulley is placed for the full tubs and another pulley for the empty tubs. The road for the tubs as they approach these pulleys is made to rise, and just before reaching the pulley a fall commences. The tub leaves the chain, passes round the curve under the pulley, and by its own momentum attaches itself to the chain again on the other side. It is questionable how far these self-acting curves are really a benefit, and we have shown how readily a branch can be worked in any direction from a main chain, so that it would be well to hesitate before trying a curve. However, the figs. 177 and 178 show perhaps as good a method as any of doing this, and there may be cases where nothing else will answer so well.

So far as connecting and disconnecting to an ordinary endless chain, the disconnection is effected by the chain approaching the pulley leaving the tub; and as regards connection, if the tub is entering a falling gradient it will attach itself, if otherwise it must be pushed sufficiently under the chain.

We now just touch upon the collieries at which the North of England Committee made experiments upon endless chains.

Hapton Valley Colliery: The mountain seam worked by a day drift. The coals brought out by this drift along the main road to a heapstead and then screened, two other roads then conveying them a distance of 2,000 yards to the canal, the hauling engine being of the type shown on fig. 165. The chain weighs 13 lb. per yard, and the general duration is twelve years. The tubs on the main road are placed 10 yards apart, and on the other roads 12 yards and 14 yards apart. The driving pulley for the chain is worked on the third motion, and so arranged that when the engine is going from 100 to 150 strokes per minute the tubs are moving from 2 miles to 3 miles per hour. To gain sufficient friction on the driving pulleys to prevent the chain from slipping it is passed two and a-half times round the driving wheel, and half a turn round the wheel at the other end. Experiments showed power required to drive engine and gearing at 120 strokes per minute, 8·6-horse power. Of the three roads the average dip to the shaft was 1 in 178, and when working, the engine running at 120 strokes per minute, the result was 69 per cent. in actual haulage, and 31 per cent. on engine and gearing. In working the main road alone, which was practically level, by the inclination in one direction counterbalancing the inclination in the other direction, the results came out 62 per cent. on the work, and 38 per cent. on engine and gearing. In working No. 1 road along with main road, which rises to the shaft 1 in 381, 61 per cent. of total power was expended upon this No. 1 road; but how much was working the gearing and how much doing the haulage is not given. No. 2 road, having a fall to the shaft of 1 in 48, seems to have just about worked itself, only ·7-horse power being needed for this road, out of a total horse-power of 23·6 exerted upon the whole system. The cost of leading coals per ton per mile down an average gradient of 1 in 178, the average distance led being 1·005 mile, and the average quantity led being 372 tons per day, is put down at 1·830d. The surface endless chain at Hapton Valley is also dealt with, but that we do not propose to touch upon. There is no real differ-

ence in principle between endless chains on surface and endless chains underground.

At Gannow Colliery the chief features in the arrangement of the endless chain system were, that the motion was transmitted by chains in the shaft, and the roads underground had heavy gradients. The chains in the shaft were of $\frac{7}{8}$ iron, whilst those underground were mostly $\frac{5}{8}$. The rise to the shaft in one underground road was 1 in 15 for a distance of 1,209 yards, and in the other a rise of 1 in 9 for a distance of 948 yards. The former dealt with 231 tons a day, and the other 144 tons, but these arrangements had previously been equal to double these amounts. Experiments showed that to work the engine and gearing alone at 101 strokes per minute 7·89-horse power were required, and to work the gradient of 1 in 9 at an average speed of one mile an hour, 16·11-horse power were required, being a percentage of 51 for haulage, and 49 for engine and gearing, being very nearly half-and-half. The cost of leading coals per ton per mile up an average gradient of 1 in 15, the average distance led being ·687 miles, and the average quantity led being 231 tons per day, is put down at 1·074d. The cost up an average gradient of 1 in 9, the average distance being ·530 miles, and the average quantity led being 144 tons per day, is given as 2·409d.

At Rowley Colliery an engine on the surface works the chain underground, and also another chain which actually winds the coals, and the reason why one small engine appears to do so much here is that the roads underground are all in favour of the full tubs, the average fall to the shaft being about 1 in 23. The gradients vary very much, being as small as 1 in 92, and as great as 1 in 3·3. The average quantity dealt with was 410 tons per day. The speed of the chain is about one and a quarter miles per hour, and the tubs placed 18 yards apart, and the tubs run upon the incline of 1 in 3·3 with perfect safety. Experiments showed that the underground roads working all together were self-acting and actually assisted the winding. The cost of leading coals per ton per mile down an average gradient of 1 in 23, the average distance led being ·668 miles, and the average quantity led being 418 tons per day, is 1·388d.

The surface endless chain at Burnley is also mentioned and the cost of working comes out very low, the cost per ton per mile down an average gradient of 1 in 68, the average distance led being 404 tons per day, is 0·551d.

The surface endless chain at Clifton Hall is described, the peculiarities of which are that no forks are used, the weight of the chain upon the tubs drawing them along; this necessitates a looser chain and a greater distance between the tubs. The tubs are generally placed about 30 yards apart, and in order to prevent the chain from touching the ground when the tubs are apart, small iron rollers are placed upon the road about 22 ft. apart, and when the tubs are 45 yards apart the chain suspended between two of the tubs touches one roller. On an incline of 1 in 33 it is found the chain will run over the tubs, and inconvenience is caused. There seems little doubt that some means of securing the chain to the tubs is required.

Reference is made to the South Wales endless chain, being an arrangement for hauling coals up an inclination of 18 in. to the yard, that being the inclination of the particular seam of coal worked. The chain is of iron, 1¼ in. diameter, and runs on rollers, and the tubs are attached to the chain singly, by means of short chains with hooks at each end.

The writer, whilst engaged on some business in Scotland, and staying with his relative, Mr. Russell, of Coltness, and ever on the alert to discover appliances coming under the comprehensive heading *The Mechanical Engineering of Collieries*, saw at work there one of the most effective examples of powerful haulage by endless chain that have ever been brought under his notice, and a description of it will make a not unfitting conclusion to the consideration of the endless chain.

It is used for working a seam of coal on the Coltness Estate at a point where it was not desirable to have a winding shaft, and consequently it is entered from the surface by a descending roadway, which has a total length of 1,782 yards, and which, whilst level at some parts, is as steep as 1 in 6½ at other places. The average

descent for the entire length is 1 in 14½, and an endless chain does the whole work.

The hauling engines are coupled, with cylinders 15 in. diameter, and geared about 4 to 1, the exact proportion being 88 and 21, and the driving pulley measures 5½ ft. diameter. The needful boilers for the generation of steam are placed upon the surface alongside the hauling engines, and fig. 179 gives a fair representation of the engines and gearing and the higher portion of the system. The tubs are of wrought iron, weighing 5 cwt. each empty, and carrying each 10 cwt. of coals. The wheels are 11 in. diameter, with axles 1½ in. diameter, the axles being turned and wheels bored. The tubs are placed under the chain at intervals of 35 yards, and reckoning a total length of 1 mile and 1 chain = 1,782 yards, gives as nearly as possible fifty-one empty tubs and fifty-one loaded tubs on the chain at one time. And as each tub carries 10 cwt., we have the load upon the hauling engine 10 × 51 = 510 cwt. = 25½ tons of coals, and the friction of tubs and chain and gearing.

The actual work being done by the hauling engines will be the vertical weight of coals moved, which we take as 510 cwt. ÷ 14½ (the average inclination being 1 in 14½) = 35 cwt.; the friction of the tubs, which, assuming a co-efficient of friction $\frac{1}{28}$, will come out 5 × 102 = 510 ÷ 28 = 19 cwt.; the friction of the chain consequent upon its own weight, which is 30 tons = 600 cwt. ÷ 28 = 21½ cwt.; and the friction of the coals 510 cwt. ÷ 28 = 19 cwt. This gives a total load upon the chain of 94½ cwt. In addition to this there will be some resistance in the driving and other pulleys round which the chain has to pass, so that we might fairly fix the total load at 5½ tons, which exactly agrees with the experiments made with the dynamometer during actual working. So substantial a corroboration of the accuracy of the co-efficient of friction—namely, $\frac{1}{28}$, adopted in these haulage chapters is gratifying. The dynamometer was also placed on the empty side at the top and at the bottom. The pull at the top of the empty side will be the weight of chain and weight of tubs on that side ÷ 14½, and the pull at the bottom of the empty side will be the weight of chain and weight of tubs on that side ÷ 28; and in these cases also actual

experiments with the dynamometer came very near the results of theoretical calculations. The chain employed has been tested to over 20 tons, thus allowing a margin of nearly 4 to 1 between the working load and the ultimate strength of the chain. Great care was exercised in the manufacture of this chain, and the selection of material and the price per ton was more than double the price of ordinary hauling chain of the same dimensions; this high expenditure showed real courage and true economy. But however strong the chain may be, accidents happen. A sudden jerk in starting will cause a link to snap, and an incident of this character upon a level road or shaft incline matters nothing, but on an incline of 1 in 14½ a mile long is something very serious.

Provision of a very ingenious character has been made to lessen the injurious results of a break in the chain. First, at the small pulley at the top of the incline which guides the chain to the driving pulley a movable catch is placed, which keeps out of action when the chain is working properly, but if a break takes place at that point, grips and holds the chain. Second, at various points of the incline, both on the full and empty roads, claws are placed upon the floor between the rails. These are never touched by the chain when in proper work, but when a break takes place and the chain falls down, it is held in these claws and no harm results. Third, the most ingenious safety arrangement is the automatic stop block, shown in fig. 180, which is placed at intervals in the full road. The ascending tubs press it down and pass over it without difficulty, and as soon as a tub has passed over it rises again to the position shown in the figure. In the event of a break in the chain, instead of loaded tubs rushing madly to destruction down a heavy incline, the space between two tubs—namely, 35 yards—is practically the maximum distance they can run, which prevents them getting to any dangerous speed; and they nicely cushion themselves against the automatic stop blocks, as shown in fig. 180.

The writer has seldom, indeed, had the opportunity of inspecting an arrangement which has given him so much pleasure and afforded so much instruction. The whole arrangement is simple, and eminently efficient for its

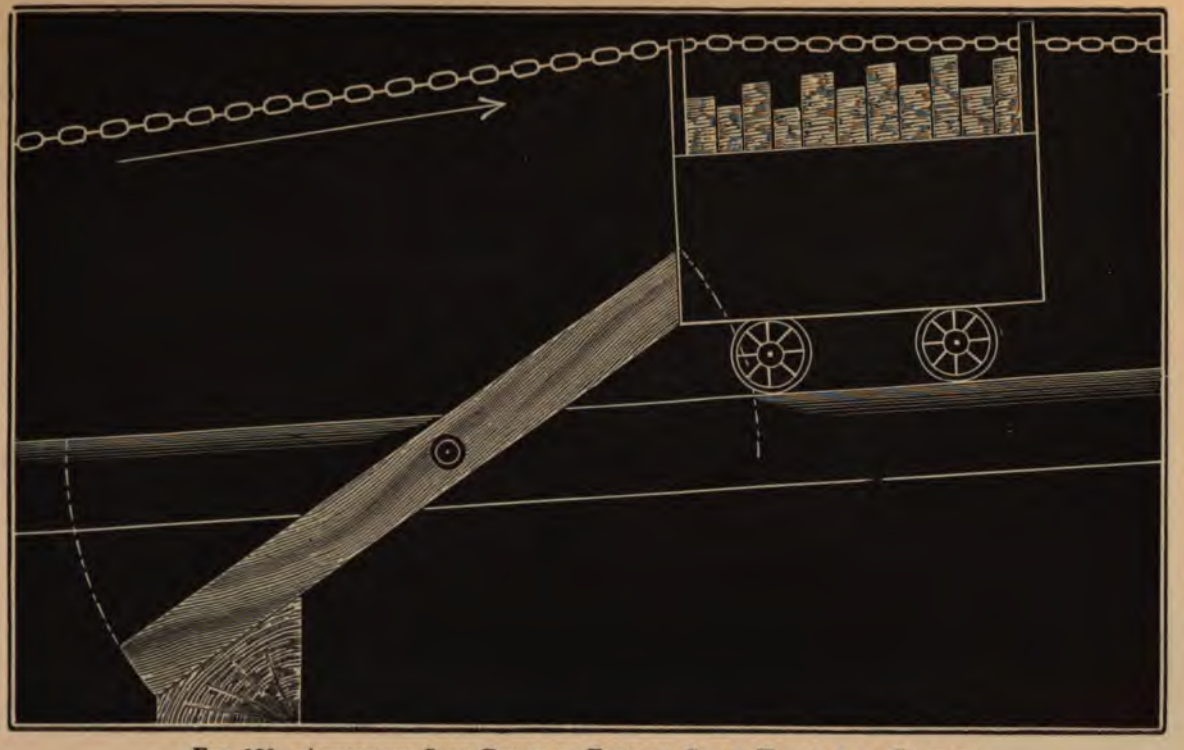


FIG. 180.—AUTOMATIC STOP BLOCK IN ENDLESS CHAIN HAULAGE AT COLTNESS.

[*To face page* 264.]

work, and the various appliances for preventing disaster from breakage of chain are excellent in their ingenuity, and reflect the highest credit upon Mr. Russell, the manager, and those who have been associated with him in the arrangement.

The following is an extract from an interesting letter received from an important colliery in the North of England:—"I have read with interest your first volume and the chapters now appearing of the second volume, including the present one, on endless chain haulage. We have a good example at this colliery, and I offer you particulars. So far as I know, it is the first case where the endless chain has been adapted to work round a curve without the use of pulleys. The drawing shaft is situated 750 yards from the screens; the first 200 yards from the shaft rises about 20 feet, at which point there is a bend of 120 degs., and then falls about 70 ft. in 550 yards to the screen. We use a $\frac{7}{8}$-chain, driven by a horizontal engine, with bevel gearing at the screen end. The tubs carry about 8½ cwt. each, are placed about 20 yards apart, and the speed is from three to four miles an hour. It was originally designed, as your article describes, with two pulleys at the bend, and the roads arranged for tubs to gravitate through. The arrangement did not work well, and several years ago we dispensed with the pulleys, and made several tubs as they passed round the curve to take the place of the fixed pulleys. The two roads were re-laid at an easy curve, and elevated the inside rails 2 in., the best elevation being arrived at by experiment. For six years this arrangement has worked well, there being no more trouble on the curve than elsewhere on the roads; and as compared with having pulleys, we find a considerable saving in power, in labour, and in repairs."

CHAPTER XXIII.

HAULAGE.—THE ENDLESS ROPE SYSTEM.

Advantages of Haulage by Endless Rope—Saving in Weight as compared with Endless Chain—Chains more frequently break than Ropes—Cases where Chains have an Advantage—Chains will work even on Defective Machinery—Ropes require good Appliances—The Endless Rope over the Tubs at Brinsop Hall Colliery, Wigan—The Endless Rope under the Tubs at Clifton Collieries, Nottingham—Power to work Endless Rope Haulage—The Best Arrangement is Engines above Ground and Ropes in Shaft—Advantages and Disadvantages of the Arrangement—Example for a Pit 700 yards Deep—The North of England Report—No. 1 and No. 2 Systems. Appliances for tightening and giving needful Friction—Method of attaching Tubs to Rope—Haulage at Shireoaks—Size of Engines—Amount of Work—Description of the Friction Driving Gear—Speed of Rope—The Useful Horse Power—The Cost of Haulage—California Colliery, Wigan—Tightening Arrangements and Driving Gear—Speed of Rope—Newsham Colliery—Attachment of Tubs to Rope—Clip Pulley—Speed of Rope—Cost of Haulage—Cinder Hill Colliery—Speed of Rope—Arrangement to give needful Friction for Driving—Method of Attaching Tubs—Conveyance round Curves—Cost of Haulage—Bridge Pit—Description of Engines and Boilers—Amount of Work done—Appliances to give Friction and obtain Tightening—Transmission of power to work Branch Roads—The Speed of Rope—Methods of Working Curves—Cost of Haulage—Scot Lane Collieries, Blackrod—Peculiar Method of Attachment—Difficulties on Light or Irregular Gradients—Mesnes Colliery, Wigan—Engines on the Surface—Tightening Appliances at Bottom of Shaft.

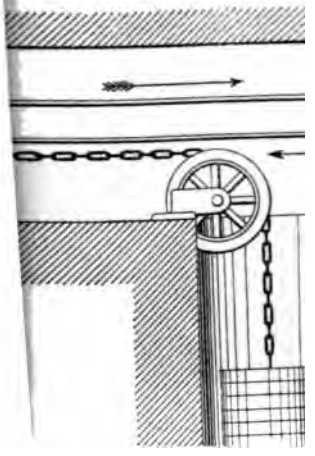
HAVING dealt with direct haulage, tail-rope haulage and endless chain haulage, we now, in our concluding chapters on haulage, take for consideration the endless rope. We have tried to show that the systems described, such as the endless arrangements at Burnley, are well adapted to the special peculiarities of the district, but

have no hesitation in saying at the outset of this chapter that the system which is already the most popular, because found the most successful, and likely to outstrip all its competitors in the future, is the endless rope. It is adaptable, practically, to any mine, whether the roads are level or have a rising or falling gradient, whether the work is all done along one main road or innumerable branches are worked, and work can be done quite easily round curves. It gives a continual delivery to suit requirements, affords a slow and therefore easy movement to the machinery, and gives the maximum of strength with the minimum of weight. It has already been shown that an endless chain, to do the same work as an endless rope, will be about four times as heavy, and this, where we have miles of road, is a serious matter. We have mentioned the contention that a chain is almost everlasting, whereas a rope has a limited duration. Chains much more frequently break than ropes, and the great difference of wear only applies on the surface, and even here, with really good material, endless ropes have done good work for six or seven years. Underground, where we have not the exposure to the weather, there is really no reason, if we have good machinery and good ropes, why ropes should not have a very long life. The real fact is that a chain will work upon anything—almost as well upon defective machinery as if it were perfect—whereas ropes rapidly go to destruction unless the pulleys, &c., are good—and in nine cases out of ten they are not only not good; they are deplorably bad.

There are two chief ways in which the endless rope may be and is applied—namely, over the tubs and under the tubs. The first arrangement is very generally adopted in Lancashire, and we propose to illustrate it by the example at Brinsop Hall Colliery, Wigan. The second arrangement is very common in the Midlands, and we take our examples from the Clifton Colliery, Nottingham. It would not be so convenient in the Midland coalfield to work with an over rope, on account of the very high loading of the tubs, which would be liable to injure either the coal or the rope. As regards power for working endless rope haulage, we can have any of the systems already spoken of—namely, engine and boilers below ground, or

engine below ground and boilers above, or engines below ground worked by compressed air. But the arrangement which it seems will become most general in the future is to have the hauling engines above ground and take the ropes down the shaft. This avoids the danger of boilers, the nuisance of steam or the extravagance of compressed air, and in practice is very effective. We require a longer rope—equal to at least twice the depth of the shaft—and this rope has to be especially strong, because it has all the haulage underground to contend with, and its own weight; and we have the friction of the weight of this rope, which on good pulleys and well-proportioned bearings will not be much. The inconvenience in the shaft is not worth considering, because whilst a direct or tail rope running at ten miles an hour in a shaft is somewhat dangerous, an endless rope working at about one mile an hour is nothing. There are no great strains and jerks, and consequently no liability to accident. Practically, there is no need for protecting it at all, but it may be shooted off altogether from the cages or made to work in wooden pipes. It may be said such an arrangement is well enough for shallow pits, where the weight of the rope in the shaft is immaterial, but it is not practicable in deep pits—say 700 yards deep. This was so no doubt years ago, when the material of which ropes were made was not at all equal to that which we can use now, possessing a tensile strength in the solid wire of over 100 tons per square inch. Let us suppose a case where the haulage is such that the actual haulage pull underground is 5 tons, which on an average inclination of 1 in 10 would represent a load of 50 tons. And suppose the pit 700 yards deep; we should require for the haulage a rope of $\frac{3}{4}$ in. diameter, and for the rope in the shaft a rope of 1 in. diameter, which really cannot at all be considered a serious matter; and even at 1,000 yards a rope $1\frac{1}{4}$ in. diameter would give ample strength. Of course with inferior qualities we arrive, at a moderate depth, at a limit beyond which a rope will not support its own weight; but no haulage arrangements can be recommended which do not comprise ropes of the highest qualities—high in strength and high in flexibility, which will take small curves without injury.

RANGEMENT FOR OBTAINING





In the North of England *Report* the endless rope systems are classified as No. 1 and No. 2 systems. No. 1, which has the rope under the tubs, is said to be in operation in the Midland counties. To give motion to the rope a single wheel is used, and friction for driving the rope is supplied either by clip pulleys or by taking the rope over several wheels. Fig. 181 shows an arrangement for obtaining the needful friction for rope, and, together with fig. 182, shows a tightening arrangement. One driving wheel is used, and the rope is kept constantly tight by passing it round a pulley fixed upon a tram to which a heavy weight is attached. (See fig. 183.) Either one or two lines of rails are used. When a single line is adopted the rope works backwards and forwards, only one part being on the wagon way, and the other running by the side of the way. When two lines are used the ropes move always in one direction, the full tubs coming out on one line, and the empties going in on the other. Examples in the North of England *Report* are taken from Shireoaks and Cinderhill in Nottingham, Elston in Yorkshire, and Newsham in Northumberland. The rope passes under the tubs, and the connection is made by means of a clamp or by sockets in the rope, to which the set is attached by a short chain. (See figs. 184 and 185.) The rope runs at a moderately high speed.

No. 2 system at that time was peculiar to Wigan. A double line of rails is always used. The rope rests upon the tubs, which are attached to the rope either singly or in sets varying in number from two to twelve. The connection between the tubs and the rope is effected by a short chain. (See figs. 186 and 187.)

The tubs are placed at a regular distance apart, and the rope works slowly. Motion is given to the rope by large driving pulleys, and friction is obtained by taking the rope several times round the driving pulley. Examples were taken from Bridge Pit, Meadow Pit, Moor Pit, Mesnes Colliery, and Scot Lane.

At Shireoaks the hauling engines, coupled, had cylinders 12 in. diameter, with 2 ft. stroke, and were fixed underground, with steam boiler close to. The amount of work done was 320 tons in a working day of ten hours.

wards and forwards round the driving wheels and the tightening pulley, as shown upon figs. 181 and 182. All the arrangements of driving wheels and tightening pulleys were under the way, the rope coming on to the wagon-way about eight yards from the driving wheel. The highest average speed attained was 11·7 miles an hour, and a full set was brought out and an empty set taken in simultaneously. There was a short curve at one place, of four chains radius, round which the set went well enough at seven miles an hour.

At Newsham only one way was used, the empty and full tubs running on the same road, and half of the rope being carried on sheaves by the side of the way. Instead of a clamp, as shown upon fig. 184, the tubs were attached to the rope by short chains, one end of the chain being secured to the tub at each end of the set, and the other attached to a socket in the rope, as shown in fig. 185. The rope worked upon a clip pulley, and the plane was undulating, necessitating an attachment at each end of the thirty-two tubs forming a set. The length of the plane was 836 yards; it was practically level, the average gradient being a fall towards the shaft of 1 in 805. At each end of the plane the rope passed under the way, and in going in and out, when the set came to this point, it was disconnected from the ropes, and the gradient of the way was so arranged that it ran by itself into the siding. The average speed was ten miles an hour, and there were two very slight curves on the plane, round which the main rope worked easily enough in the centre, and the rope by the side of the way was taken round these curves by three pulleys. The labour cost for an output of 400 tons per day was put down at 14s. 9d.

At Cinder Hill the arrangements were somewhat different, as the hauling rope worked at a slow speed, and took several sets in and out at the same time. The needful friction for driving the rope was obtained, as shown upon figs. 181 and 182, by passing the rope backwards and forwards around several pulleys, as many as five being used in this particular case. The length of the engine plane was 1,170 yards, and there was a double line of way, the full and empty tubs running on different roads. The plane was level throughout; there were no branches, and

there was one curve which is 66 yards in radius. The speed of the rope was two and a-half miles an hour, and the usual number of tubs in a set thirty-six, and generally there were two sets on each road. The method of attachment was as shown upon fig. 184. At the curve referred to rollers were placed five yards apart, and between each pair of rollers there was a small drum sheave, and round these rollers and sheaves the set, with its clamp, passed without any difficulty. The cost of hauling the coals on this plane was given at 2d. per ton per mile.

The foregoing were taken as illustrative of endless rope system No. 1, in which the hauling rope worked under the tubs. Now we have the examples of endless rope system No. 2, in which the hauling ropes worked over the tubs.

At Bridge Pit the arrangement was somewhat extensive, and was worked by a pair of horizontal engines, having cylinders 20 in., and stroke 3½ ft., engines and boilers being underground, 150 yards apart. There was a main driving rope from a pulley 14 ft. diameter, and this main rope transmitted power to all the rest. The quantity of coals dealt with was 400 tons per day. All the planes had a double line of way, one line for empties and the other for loaded tubs. The average gradient was a rise to the shaft of 1 in 62, and excepting one curve all the planes were quite straight. The needful friction was obtained by passing the rope two and a-half times round the driving pulley, and the needful tightening was effected by a movable carriage, as shown on fig. 183, but instead of having a weight passing over a pulley and hanging in a staple, the carriage was connected to a fixed upright by means of a chain and tightening screw. The main rope transmitted power to the different branches by double pulleys on the same shaft, one for the main rope and one for the branch rope, and either branch could be thrown out of gear. The tubs went in and out in gangs of two, 20 yards apart, and were connected to the rope as shown upon fig. 186, sometimes at one end only, and in some cases at both ends. The average speed was low, being less than 1¼ miles per hour. There were two curves; in one case the angle was 72 degs., and the motion was transmitted

from one pulley to another; there being two ropes the tubs had to be disconnected and reconnected. The other had an angle of 118 degs., and the ropes were taken round two pulleys, each 4½ ft. diameter. These pulleys were made with a large flange on the lower side and the tubs passed round comfortably.

The cost of leading coals per ton per mile up an average gradient of 1 in 62, the average distance led being ·602 mile, and the average quantity led being 400 tons per day, was 3·816 pence.

At Scot-lane Collieries the most interesting feature was the method of attachment, as shown upon fig. 187. Strong loops of hemp were fastened on the rope by a wrapping of string at regular distances apart. One hook of the chain was first attached to the tub, and the hook at the other end was then passed through the loop, as shown in fig. 187. The tubs were sent along the plane, one at a time, and as the gradient of the plane was very regular, only one chain was necessary for each tub. The heavy inclination caused the tubs to keep a constant weight upon the chain; on a light gradient the hook might slip out of the loop. These loops were made of hemp, 1 in. in diameter, and lasted about four months; they were found strong enough to draw twelve tubs at a time up the plane. They were fixed on the rope, 17 yards apart, thus making a regular supply of full and empty tubs necessary. In the first instance the needful friction was given to the hauling rope by passing it one and a-half times round the driving pulley, and the loops passed round the pulley without causing any inconvenience. The system would not be so easily applicable to an irregular plane, where two loops would have to be provided for each tub or set of tubs.

Mesnes Colliery haulage arrangements were reported upon and presented no feature separate from the foregoing, except that the engine was placed upon the surface and worked the driving rope down the shaft. This driving rope was coiled two and a-half times round the driving wheel at the surface, and at the bottom of the shaft there were two pulleys placed close together on the same shaft. The driving rope passed two and a-half times round one of the pulleys, and the rope working the

plane was driven by the other pulley and passed two and a-half times round it. The rope in the shaft, which was 314 yards deep, was kept tight by having a sliding-carriage for the shafts of the two pulleys at the bottom and attached to it a screw.

Such give a fair idea of endless rope haulage when the North of England Committee made their *Report* in 1867, and no more accurate or useful record of mining appliances has ever been published in any language. Now we have to deal with endless rope haulage as we have it in 1884, taking as examples of really good modern haulage, Brinsop Hall Colliery, Wigan, and Clifton Colliery, Nottingham.

CHAPTER XXIV.

ULAGE.—THE ENDLESS ROPE SYSTEM AT BRINSOP COLLIERIES.

Brinsop Hall Collieries, Wigan—Mr. A. H. Leech—Mr. W. lding, of Cossall Collieries, Nottingham—Messrs. John Wood Co., Engineers, Water Heyes Foundry, Wigan—Description the Brinsop Haulage—Tightening Appliances in the Mine—thod of working Branch Roads—Amount of Work done—Cost Haulage—Life of Ropes—Extravagance of Compressed Air—cification of a Pair of Horizontal High Pressure Hauling En-es—Steam Cylinders—Pistons and Rods—Cross-heads—Slide rs and Blocks—Connecting Rods—Cranks—Crank Shaft and destals—Fly-wheel—Valve Motion—Foundation Plates—Gear and C Pulleys—Defectiveness of C Pulleys—Proposed endment—Advantages of Grooved Pulleys—Haulage Arrange-nts at Rainford Collieries—Mr. T. Y. Greener—Self-contained uling Engines—John Wood and Co.'s Experience in Colliery chinery—Freedom from Mishaps with Ropes at Brinsop—reful Inspection—Speed of Hauling Ropes—Method of attach-Tubs—Advantages of the Chain over the Fork.

writer knows of no better system of haulage by end-rope than that which some half-dozen years of regular has proved efficient at the Brinsop Hall Collieries, Wigan, now under the management of Mr. A. H. h, to whom the writer is much indebted for kind tance. The haulage was designed and set to work ng the period when Mr. Wm. Holding, now of Cossall ery, Nottingham, had the management, and the en-ers who designed, constructed, and set to work all the hinery were Messrs. John Wood and Co., of Water es Foundry, Wigan, long distinguished for excellence l branches of colliery machinery. Figs. 188 and 189 trate this very excellent arrangement, fig. 188 showing

CHAPTER XXIV.

HAULAGE.—THE ENDLESS ROPE SYSTEM AT BRINSOP COLLIERIES.

The Brinsop Hall Collieries, Wigan—Mr. A. H. Leech—Mr. W. Holding, of Cossall Collieries, Nottingham—Messrs. John Wood and Co., Engineers, Water Heyes Foundry, Wigan—Description of the Brinsop Haulage—Tightening Appliances in the Mine—Method of working Branch Roads—Amount of Work done—Cost of Haulage—Life of Ropes—Extravagance of Compressed Air—Specification of a Pair of Horizontal High Pressure Hauling Engines—Steam Cylinders—Pistons and Rods—Cross-heads—Slide Bars and Blocks—Connecting Rods—Cranks—Crank Shaft and Pedestals—Fly-wheel—Valve Motion—Foundation Plates—Gearing and C Pulleys—Defectiveness of C Pulleys—Proposed Amendment—Advantages of Grooved Pulleys—Haulage Arrangements at Rainford Collieries—Mr. T. Y. Greener—Self-contained Hauling Engines—John Wood and Co.'s Experience in Colliery Machinery—Freedom from Mishaps with Ropes at Brinsop—Careful Inspection—Speed of Hauling Ropes—Method of attaching Tubs—Advantages of the Chain over the Fork.

The writer knows of no better system of haulage by endless rope than that which some half-dozen years of regular work has proved efficient at the Brinsop Hall Collieries, near Wigan, now under the management of Mr. A. H. Leach, to whom the writer is much indebted for kind assistance. The haulage was designed and set to work during the period when Mr. Wm. Holding, now of Cossall Colliery, Nottingham, had the management, and the engineers who designed, constructed, and set to work all the machinery were Messrs. John Wood and Co., of Water Heyes Foundry, Wigan, long distinguished for excellence in all branches of colliery machinery. Figs. 188 and 189 illustrate this very excellent arrangement, fig. 188 showing

the general arrangement in plan, and fig. 189 being an elevation. The system is very easy to understand, consequently no lengthy explanation is at all required. The hauling engines, of which we give plan and elevation (see figs. 190 and 191), are placed upon the surface, and having spur gearing, the driving rope works off a pulley on the third motion shaft, the proportion of gearing being about 9 to 1. This driving rope, which is one inch diameter, passes over a pulley at the top of the pit, and goes down the shaft, which has a depth of about 300 yards. On reaching the bottom there is another pulley at right angles to the one on the surface, and the rope passes round this second pulley. From the pit bottom the rope makes a kind of circuit, making a coil round other pulleys, fixed here and there, which belong to so many branch roads.

Finding its way back to the pit bottom there is another pulley which directs the rope up the shaft, round another pulley at the surface, and on to the driving pulley at the engines. This constitutes what we call the strap rope, or main driving rope, which obtains the needful friction by being coiled several times round the driving pulley, and retains the needful tightness in the shaft by its own weight, and in the mine by a stretching arrangement fixed at one point, and as the same principle of tightening prevails all through the pit, a word here will describe it. A pulley round which the rope works is attached to a wooden frame which can slide upon a fixed frame. This sliding-piece is connected to a fixed timber by tightening screws, which draw up or let out as may be needed. Theoretically this is not so effective an arrangement as the suspended weight, which is free to rise when the rope contracts and to fall when the rope expands. But in practice a rope does not contract, and as regards lengthening, this pretty nearly all takes place shortly after a new rope is set to work, and the screw-tightening arrangement does well enough. So much for the main rope. From each of the pulleys round which the main rope coils in its circuit of the mine a branch is worked, and the method adopted is simple enough. On the vertical shaft the large pulley attached to the main rope is at the top, and a smaller pulley at some distance below and loose

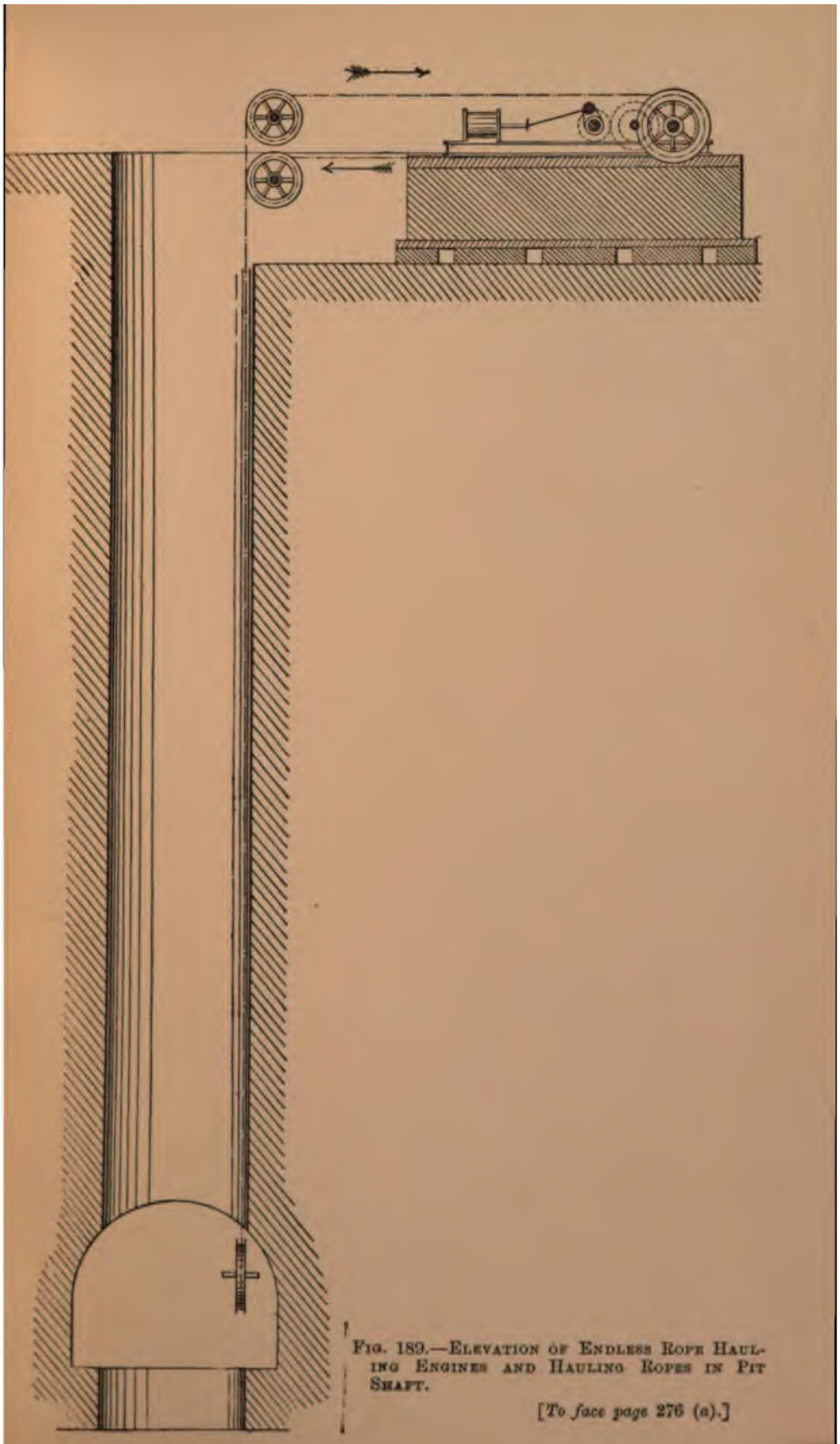


FIG. 189.—ELEVATION OF ENDLESS ROPE HAULING ENGINES AND HAULING ROPES IN PIT SHAFT.

[*To face page* 276 (*a*).]



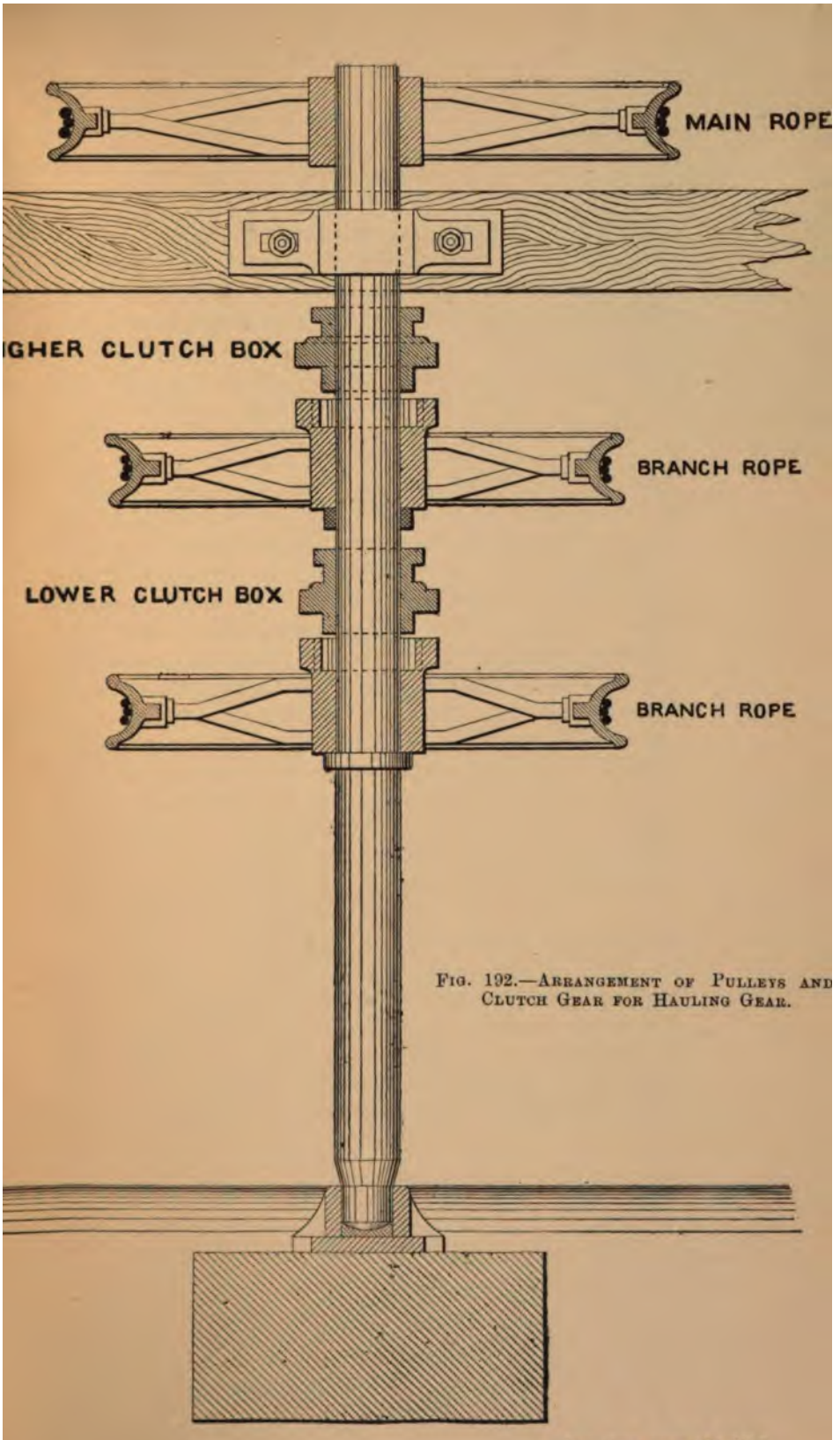


FIG. 192.—ARRANGEMENT OF PULLEYS AND CLUTCH GEAR FOR HAULING GEAR.

[*To face page 276 (c).*]

upon it. (Fig. 192 shows the main pulley and two smaller pulleys for two branches.) When the branch is idle the larger pulley only is at work; when the branch is working, a catch box throws the smaller pulley in gear. Each branch may be any length (and may in its turn have any number of branches), and has a tightening arrangement of the far end. At present there are some four branches worked, the longest of which is about half-a-mile, and the output is 600 tons in ten hours. There is no confusion in the mine; the machinery does its work as well-regulated machinery should do, and dealing with every pound of coals got, places it in the cage ready for the winding engine at a cost not exceeding 1¾d. a ton. A much larger number of branches could be worked from the same driving rope if the output required them, and the output under this arrangement of haulage, so far as mechanical arrangements are concerned, could be considerably greater, and in such a case the cost would be less. The various ropes have a long life, and the engines and gearing generally work as comfortably and almost as noiselessly as if they had nothing to do. A second driving rope, driven by the same engines on the same shaft, passes down another pit, and the same principle and arrangement repeated. Fortunately the gradients are not heavy, and consequently the hauling engines are not large.

Figs. 190 and 191 illustrate the Brinsop Hall engines and gearing, and the makers—Messrs. John Wood and Co., of Water Heyes Foundry, Wigan—having large experience and successful results with this class of machinery, have kindly furnished the following, as descriptive of even more powerful engines and gearing of the same class, made some time ago, and now working with great success:—

SPECIFICATION

Of a Pair of Horizontal High-pressure Hauling Engines, 15 in. Cylinder, 30 in. Stroke, Gearing 16 to 1 with two Driving Pulleys, each 9 ft. diameter, designed, constructed, and erected by Messrs. John Wood and Co., engineers, Water Heyes, Wigan.

Steam Cylinders.—To be two in number, 15 in. internal diameter when finished, of sufficient length to work a stroke of 2 ft. 6 in., of very hard metal, carefully and truly bored, bell-mouthed and faced at the ends. Flanges to be 1½ in. thick when finished, and cylinder, when bored out, to have metal at least 1⅛ in. thick. Cylinder ends to be fitted with cast iron covers, turned and faced, one cover to each cylinder to have stuffing box cast upon it, bushed with brass, and fitted with cast iron gland bushed with brass, both truly bored to fit piston rods. Cylinder castings and covers to be free from all blowholes, sandholes or other imperfections. Pistons to work over bell-mouthing at each end. Cylinders to have strong brackets cast on them to secure them to foundation plates, the bottom of which must be truly planed, also projections to fit inside of bed-plates. Cylinders to have valve chest cast on with all needful steam and exhaust ports and branches, stuffing boxes, &c. Steam ports to have an area of 12½ square inches. Steam pipe to be 4 in. diameter. Exhaust ports to have an area of 19½ square inches. Exhaust pipe to be 5 in. diameter and placed under cylinder. Ports to be as long as convenient, and to be accurately gauged and trimmed, the tops and bottoms being left semi-circular where valve works over. Port faces to be accurately planed, and the valves must work over facings at each side. The flanges of valve chests to be planed, also other places requiring it. A suitable valve chest cover to be provided for each box of cast iron, and truly planed and faced. Bolts for securing cylinder covers and valve box covers to be ¾ in. diameter, and not more than 5 in. pitch. Stuffing box for valve spindle to be entirely bushed with brass, and to be

fitted with cast iron gland, brass bushed, and bored to fit valve spindle. Cylinder covers to be fitted with self-acting waste water escapements, and valve boxes to be provided with one ¾ in. gland tap each, for taking waste water away. One indicator tap to be fixed at the end of each cylinder.

Pistons and Rods.—The pistons to be cast iron, 4 in. deep, accurately turned to fit inside of cylinder. To be as light as possible consistent with strength. To be fitted with cast iron spring rings, two in number, in one groove. Section of rings to be ⅝ in. × ½ in. Piston rods to be of Bowling iron or the mildest Bessemer steel, 2¾ in. diameter when finished; truly and cylindrically turned and fitted into pistons. The rods to be secured to pistons by being screwed into them and back side riveted over. The other end of rod to be reduced down and prepared for crosshead.

Crossheads.—To be of the best hammered scrap iron, truly bored to receive piston-rod ends, and turned for tail piece of slide blocks and for ends of connecting rods. Journals to be 4½ in. long × 3 in. diameter.

Slide Bars and Blocks.—The bars to be of cast iron, of sufficient thickness to work a stroke of 30 in., truly planed and fitted together and to the bed-plates by strong wrought-iron bolts, nuts and washers. Top slide bars to be made so that they can be taken off without disturbing bottom bars. Bottom bars to have steady pins through bottom flanges into foundation plates; bottom bars to be dished to form oil troughs to retain the oil. Slide blocks 10 in. long × 4 in. broad × 4 in. deep, and to work over faced portion of slide bars at each end of stroke. Slide bars and blocks to be truly planed and scraped.

Connecting Rods.—To be of the best hammered scrap iron, to be 7 ft. long from centre to centre of journals, and to be fitted with brass steps, wrought-iron gibs, straps and cotters. Diameter of small end of connecting-rod next crosshead 3 in., at the other end 3¼ in., at middle

4 in. To be turned all over and neatly swelled. Journal at crank pin end to be 3½ in. diameter × 5 in. long. Journal at crosshead end to be 3 in. × 4½ in. long. Brasses to be ½ in. thick at crown and ¾ in. at sides. To be truly bored out to fit journals and scraped to a fit.

Cranks.—To be two in number, and of the best hammered scrap iron, truly bored, to receive crank shaft and crank pin. Both to be shrunk on hot with ½ in. for contraction. Crank pin to have a collar on front end ¼ in. broad and ¼ in. thick; to be riveted over at back side. Hole for crank pin to be ½ in. taper. Cranks to be securely keyed on to shaft at right angles to one another. Large boss 15 in. diameter × 5 in. thick. Small boss 8 in. diameter × 3½ in. thick. Web at centre, 9 in. × 2½ in.

Crank Shaft and Pedestals.—Crank shaft to be of the best hammered scrap iron, without flaw. To be 7½ in. diameter in plain part of shaft, and turned all over. To have two journals, each 6 in. diameter × 9½ in. long, with good rounds at corners. Pedestals to be two in number, carefully and accurately fitted up and bored out to suit crank-shaft journals, 6 in. × 9½ in. To be fitted with brass steps top and bottom, and secured with wrought-iron bolts, nuts and washers. Brasses to be ½ in. thick at bottom and ¾ in. at sides. Pedestals to be angular at legs.

Flywheels.—To be 7 ft. diameter, bored out to fit crank shaft, and securely keyed by wrought-iron keys. To be not less than two arms, and to be cast in halves. Joints to be planed and secured by bolts, dowells, and screws. Face to be turned to receive brake strap.

Valves and Gear.—The valves to be of cast iron, truly planed and faced, and both inside and outside edges accurately planed and squared. To have lap on the steam side of ⅛ in. out of a two-inch stroke, and set with no lead. Lap to be put on exhaust side. Valve spindles to be of steel 1¼ in. diameter, shirted with gun metal where they work through stuffing-boxes, and to go through valve and secured thereto by two nuts at each end. Spindles to work through cast-iron guards fixed with brass steps top and bottom, and at this point

he spindles must be square, with corners horizontal and vertical. Links to be of steel worked out of solid block, and to be suspended by side links from the centre of links. The eyes of eccentric rod, where joined to link, to be not less than three times the travel of the valves apart. Eccentric rods of wrought iron, the eyes to be steeled and case-hardened, as also all the eyes, jaws, and pins in motion. No pin in motion to be less than 1 in. diameter, and eyes of rods, &c., to be made large enough to stand repeated re-boring. Eccentric hoops to be of cast malleable iron. Oil boxes to be cast on hoops with suitable hinged lids. Eccentric sheaves to be of cast iron, 2½ in. broad on working part. Eccentrics to be driven from drag crank so as to reduce the size of eccentrics. Each eccentric to be securely keyed to drag crank, and to have a capped steel set screw. Reversing shaft to be 3 in. diameter, slightly bossed up where levers fit on, and turned all over; to be supported on three pillars, fitted with brass steps, and to have all necessary levers carefully bored out and keyed on, also balance lever and weight. One pillar to be made with quadrant, and the reversing lever to be of an approved description; the quadrant of wrought iron to have two sides to it, with reversing lever working between.

Foundation Plates.—To be two in number, about 7 in. deep and 6 in. broad on top; to be on the box-section principle, and to have preparations cast on for crank shaft pedestals, slide bars, cylinders, valve spindle guards, reversing shaft pillars, and other places requiring them. Strong snugs to be cast on for crank shaft pedestals, and wrought keys carefully fitted in. Snugs to be cast on also for front feet of cylinders, and wrought-iron keys inserted. Eight bolt-holes to be cast in each plate for holding down bolts 1½ in. diameter on thread. Such holes to be chambered out inside of bed plate, and to have fillets cast round for nuts to bed against. Ready means of access must be provided to all bolts which secure parts of engine to plates, so as readily to take the whole to pieces without disturbing plates. The section of plate to be submitted for approval, and all facings must be planed to one rise or level. The front of each bed plate to be prepared to receive the part which carries gearing.

Gearing and C Pulleys.—Gearing to consist of one pinion wheel on crank shaft, 6½ in. broad on teeth and 2½ in. pitch, truly bored out and firmly keyed on to crank shaft. Second shaft 9 in. diameter, of the best hammered scrap iron, turned all over. Spur wheel on second shaft 6½ in. broad and 2½ in. pitch. Pinion wheel on second shaft 8 in. broad and 3 in. pitch. Third shaft 11 in. diameter, turned all over. Spur wheel on third shaft to be 8 in. broad and 3 in. pitch. All spur and pinion wheels to be shrouded up to their pitch lines. Shrouds ⅝ in. thick, and all spur wheels to be cast in halves, and all wheels to be securely fastened on to shafts by wrought-iron keys carefully fitted in. Gearing to be 16 to 1, or thereabouts. Angle pedestals for third shaft to be 9 in. diameter and 14½ in. long. Pedestals for second shaft 7 in. diameter and 11½ in. long. All to be fitted with bottom brass steps and cast-iron top steps, carefully and accurately bored out and fitted to journals, and to be secured by wrought-iron bolts, nuts, and washers. Pedestal plates to be of the same mould as bed plate, and joined to them by wrought bolts, nuts, and washers; to have extra strong joggles for the pedestals to be keyed against, and to have preparations, three in number, for holding down bolts, all of which must be truly planed. Two segment C pulleys to be fitted on third shaft, each 9 ft. diameter at bottom of C, with cast iron bosses and arms, clutch boxes, and all necessary arrangements for throwing either one or both pulleys out of gear. The ends of arms where segments come to be turned up truly. Preparations to be cast on arms for brake plane, 8 ft. diameter by 6 in. broad on working part, and brake planes to be securely fastened to arms by wrought-iron bolts, nuts, and washers. Segments to be cast in white iron or No. 8 pig, and to be securely bolted to arms of spiders by wrought nuts, bolts, and washers.

Contractor to provide all levers, straps, jaws, pins, pedestals, &c., for brakes and clutch boxes complete to back end of cylinders. The centres of the engines to be 7 ft.

About the only defect that occurs to the writer in connection with the above specification, or the gearing at

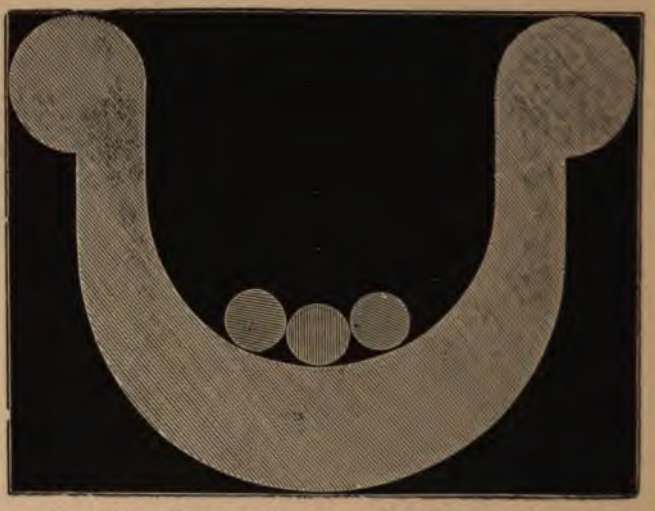


FIG. 193.—WORKING PART OF "C" HAULING PULLEY WHEN NEW.



Brinsop, is in the C pulleys, which, having several coils of the rope side by side, set up an injuriously grinding influence upon the ropes themselves, throw frictional resistance upon the engines, and wear away the pulley. Mr. Leech called the writer's attention to the curious shapes of working parts of C pulleys caused by wear of ropes, and also an amendment which he had adopted to avoid this injurious influence, but more especially upon the ropes themselves. The idea is to retain the curved form but make the diameter or circumference on which the rope enters larger than that on which it leaves. Fig. 193 shows the working part of the pulley when new; fig. 194 shows the effect of several years' wear, and fig. 195 shows the amendment, which has been attended with considerable success. Fig. 196 shows the pulley complete. The best remedy however, is to dispense where possible with C pulleys altogether, and substitute the arrangement whereby a pulley has several separate grooves, and the needful friction is obtained by having two such pulleys opposite to each other, and the rope passes round them a sufficient number of times to produce the needed friction.

Messrs. John Wood and Co. have just designed and completed an arrangement of haulage under the supervision of Mr. T. Y. Greener, at the Rainford Collieries, which, comprising all the effectiveness of the Brinsop haulage, has avoided the C form of pulleys and adopted those with grooves.

By the kindness of Mr. Greener, the writer has had the opportunity, whilst this chapter was in preparation, of seeing this hauling machinery at work, and was much pleased. There may be some one or two points of detail in which experience will suggest improvement, but the principle of the arrangement is correct, reflects great credit on the engineers who designed and made it, and will prove an economical and efficient, as it is unquestionably an important part of the colliery plant. The same firm have designed an excellent and ingenious arrangement of haulage for another large colliery.

The hauling engines are fixed not on the surface but at a mouthing off the shaft, at which place there were steam boilers. From here the hauling rope passes down the shaft, calls at intermediate seam, and passing round

a pulley transmits power to an endles
bottom of the mine and works a numl
already explained. (See fig. 197.)

The writer would have been glad i
chapter had allowed detailed and illust
a class of machinery which is deserve
popular, and is known as the self-
engine, which compactly combines in a
necessaries for transmitting power to c
of haulage. It must suffice to say
Wood and Co., Wigan, have supplied
many leading collieries in various par
it has never failed.

The ropes under the system at Br
exceedingly good life—some at work n
use since the arrangement commenced
not protected in the shaft, and have
their freedom from accidents of this k
to the use of thoroughly good rope
thorough inspection, which exposes a
infancy, and consequently avoids disast
speed of the hauling ropes is 1½ miles
each driving pulley the rope coils tw
The gangs are attached in sets of four,
as well as in front—not because the
this, but because it is found more con
tilting the tubs when the engines for
be reversed. Formerly, instead of
used, which, fixed in sockets at the en
free to turn, and in turning grippe
system did not answer so well, and w
influence upon the rope. The atta
answers very well and is practically no



CHAPTER XXV.

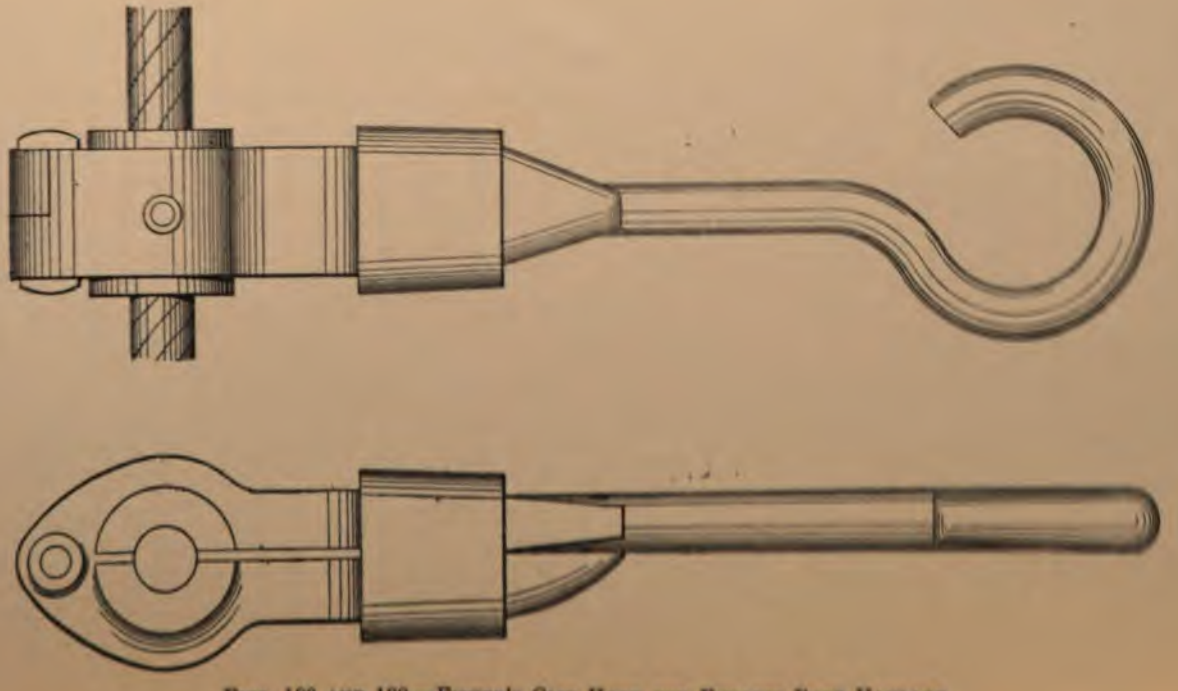
HAULAGE.—THE ENDLESS ROPE SYSTEM AT CLIFTON COLLIERY, NOTTINGHAM.

Ropes working under the Tubs—Mr. Henry Fisher—Paper before the Chesterfield and Derbyshire Institute of Engineers—Comparison between the Slow-working Endless Rope and (first) the Endless Chain, (second) the Tail Rope, (third) the Quick-running Endless Rope—Different kinds of Driving Wheels—The Clip Wheel—The Ordinary C Pulley—Pair of Grooved Wheels—Disadvantages of Clip Wheels—Grooved Driving Wheels are the best—Improvement in form of C Wheels—Lining of Cast Steel—Attachment of Tubs to Rope—Special Requirements—Fisher's Patent Clip Hook—Details of Construction—Guide Pulleys for enabling Tubs to pass round Curves—Hauling Engines at Clifton—Speed of Rope—Fisher's Friction Clutch—Details of Construction and Principle of Action—Its general Applicability to all Machinery that has to be thrown in and out of gear—Its special Advantages—Concluding Remarks on Haulage—What is the best System of Haulage?—Mr. C. E. Rhodes, of Car House Collieries, Rotherham—The Aldwarke Main Collieries—Forged Steel Wheels for Colliery Tubs by Mr. W. Eyre, of John Brown and Co.—Construction and Advantages of the Wheels.

The system of endless rope haulage with ropes working under the tubs is in great repute in the Nottingham coal-field, and nowhere to greater advantage than at the Clifton Collieries. Mr. Henry Fisher, the manager, tells us in his paper before the Chesterfield and Derbyshire Institute (and which paper is as clearly written and as elaborately illustrated as any paper to be found in the *Transactions* of any of our learned societies), that for a good many years he has given considerable attention to the question of haulage, and has visited the best arrangements in the

Kingdom. After carefully weighing all the advantages of the endless chain, the tail rope, and several modifications of the endless rope, he came to the conclusion that a slow-working endless rope passing under the tubs was the best. The result of his considerations is to be seen in the very elaborate haulage arrangements now working with so much success at Clifton, and about which we shall take the liberty of speaking, and in the interests of our readers shall help ourselves freely to Mr. Fisher's matter and illustrations. Mr. Fisher contends that, as compared with the endless chain, he gets all its advantages—namely, (1) its applicability to working branch roadways, (2) undulating and inclined roadways, (3) the counterbalancing action of the gravity of the trams on undulating and inclined roadways—and, in addition, he had considerably less weight in the rope than in the chain, and could work curves without the attention of a man or boy. As compared with the tail rope, he had all the advantages claimed for that system regarding (1) working branch roadways, (2) stations, (3) curves, (4) undulating roadways, and, in addition, had the special advantages of needing less length of rope, less wear and tear, less liability to accident, and less consumption of coal. As compared with a quick-running endless rope with tubs in gangs, this system dispensed with (1) the clamp for attaching the trams to the rope, which sometimes causes injury, (2) dispensed with run-riders, (3) had less wear and tear, and (4) less liability to accident.

The first thing to be decided upon was the kind of driving-wheel to be adopted. There were three kinds of driving-wheels found to be in use—(1) the clip pulley, (2) the ordinary driving pulley with the rope coiled several times round it, (3) a pair of grooved wheels with the rope coiling partly round each of them four to six times. Clip pulleys cannot be recommended. Of course they give a good grip to the rope, but in doing so they injure it and shorten the life of the rope. Grooved driving wheels, to which we have already referred, answer admirably, because there is no friction of one coil against another, and there is no gripping. Experiments with regard to the ordinary driving wheel, with the rope coiled several times round, have shown that if the driving-wheel was made of a



FIGS. 198 AND 199.—FISHER'S CLIP HOOK FOR ENDLESS ROPE HAULAGE.

[*To face page* 287.]

conical form, with the rope running on at the greater diameter, and off at the lesser diameter, there was scarcely any wear on the rope by the friction of one coil against another, and this has now been verified by several years' working. As ordinarily made, the rope gradually and too often rapidly wears into the working part of the driving pulley, because the rope is harder than the pulley, and this grooving proves injurious to the coiling of the rope. A lining of crucible cast steel has altogether stopped the wear upon the pulley. It is useful, no doubt, to know how such driving pulleys can be used to the most advantage, because they are the cheapest arrangement. But the best method is to have the two grooved driving wheels.

Having decided upon the kind of driving wheel comes the question of adopting some means of attaching the trams to the rope, so as (1) to be capable of being easily and quickly connected to and disconnected from the rope, (2) to hold on the rope either uphill or downhill, so as to require only one attachment on undulating roadways, (3) to be capable of working past the pulleys at the curves, and (4) not liable to damage the rope. The form of clip hook is shown on figs. 198, 199, and does great credit to its inventor, Mr. Fisher. They can be made either of wrought iron or steel. Their application is easily understood. The clip part of the hook is fitted with interchangeable bushes, so that when the hole has worn too large to grip the rope they can be replaced at a trifling cost, and the hooks will last for several years. The strength of which the hook is made is proportionate to work to be done. When a tram gets off the rails the bow part of the hook straightens and prevents any injury occurring to the rope. Figs. 200, 201, 202 show how the rope is taken under the road, or, should we rather say, the road taken over the rope, at a junction. These figures also show the working round a curve, and how, by means of guide pulleys properly placed, the clip hook passes round without trouble. As to the engines at Clifton, we need say but little, because they in no way affect the special principles of the system which we are describing. They are horizontal, with gearing about 6 to 1, and worked by compressed air, and are close to the pit bottom. There is nothing special in the driving wheel and the tightening



201.—Elevation of Tubs passing Round Guide Pulleys on a Curve.

[*To face page* 288 (*a*).]

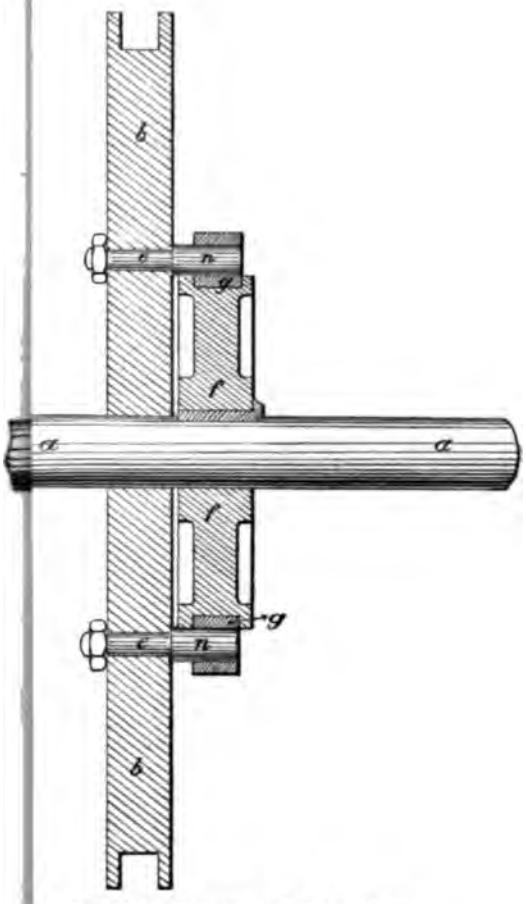
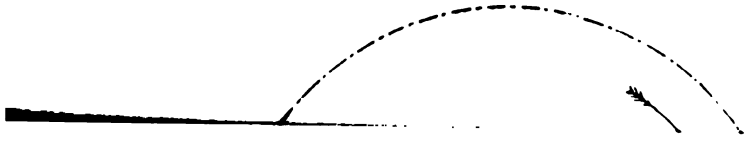


FIG. 209.—SECTION ON LINE 9-10.

[*To face page* 288 (*c*).]









result of Mr. Fisher's unceasing inventiveness in connection with hauling machinery. It is well shown upon figs. 203, 204, 205, 206, 207, 208, 209, 211, and the corresponding parts on all the figures are shown by similar letters. These seven figures form a set, and must be taken together to make the whole principle and detail of the clutch thoroughly clear.

The driving wheel, *b*, is made to run loose on the shaft *a*, when the clutch is out of gear. On the boss, *c*, of the driving wheel, *b*, is keyed a disc plate, *d*, with four or other number of pins, *e*. The disc plate thus fixed to the boss, *c*, revolves with the driving wheel, *b*, when the clutch is in gear, and remains at rest when the clutch is out of gear. A friction wheel, *f*, with turned groove, is keyed on to and revolves with the driving shaft, *a*. On the friction wheel, *f*, is a clip, *g*, made in four or other number of segments, both ends of each segment of the clip being made with projections, *h*. The projections, *h*, are made with recesses, *l*, fitted with brass nuts, *m*, chased with screw threads, in which work right and left hand threaded screws, *k*. Each segment of the clip, *g*, is made with a swell and pin hole, *n*, which receives the pins, *e*, on the disc plate, *d*. On the right and left hand threaded screws, *k*, are fixed levers, *o*, which are connected with the arms, *p*, of the sliding-box, *q*, by the links, *r*. On the sliding-box, *q*, is a groove, *s*, in which the levers, *t t*, on the rocking shaft, *o*, work to move the sliding-box on the driving shaft, *a*, in the usual way. When the sliding-box, *q*, is made to slide on the driving shaft, *a*, motion is communicated to the right and left hand threaded screws, *k*, by the links, *r*, and levers, *o*, by which means the clip, *g*, opens and allows the friction wheel, *f*, to revolve freely with the driving shaft, *a*, while the driving wheel remains at rest. When the sliding-box, *q*, is made to slide on the driving shaft, *a*, in the opposite direction to that described, motion is communicated to the right and left handed screws, *k*, as already described, by which means the clip, *g*, closes and grips the friction wheel, *f*, which, being keyed on to the driving shaft, *a*, causes the clip, *g*, to revolve with the friction wheel, *f*, and carries round with it the disc plate, *d*, and driving wheel, *b*, by the pins, *e*.

The right and left hand threaded screws, *k*, can be arranged so that the clutch can be put into gear by moving the sliding-box, *q*, either towards or from the driving wheel, *b*, as may be required, and put out of gear by moving the sliding box in the opposite direction to that required for putting the clutch into gear. As the sliding-box, *q*, can be slid on the driving shaft, *a*, to communicate motion to the right and left hand threaded screws, *k*, either to open or close the clip, *g*, both when the driving shaft is at rest and running, the clutch can be put into or out of gear, as may be required, whether the driving shaft is at rest or running. As the clip, *g*, can be gradually closed to grip the friction wheel, *f*, by the gradual motion of the right and left hand threaded screws, *k*, the driving wheel, *b*, can be gradually set in motion from a state of rest until it has attained the required velocity.

The clip, *g*, can be adjusted to grip the friction wheel, *f*, by the amount of motion given to the right and left hand threaded screws, *k*, so as to move a given load, or overcome a certain amount of resistance, and to slip in case of an undue additional strain being communicated to the driving wheel, and so prevent breakage of the machinery and ropes.

Fig. 203 shows a view of the driving shaft, driving pulley, and clutch. Fig. 204 shows a view of the driving shaft, disc plate, and driving wheel. Fig. 205 shows a view of the driving shaft, friction wheel, and clip. Fig. 206 shows a view of the sliding-box and arms. Fig. 207 shows a sectional view of the driving shaft, driving wheel, and clutch. Figs. 208 and 209 show an alternative method of fixing the pins, *e*, in the arms of the driving wheel to dispense with the use of the disc wheel, *d*. Fig. 209 shows a sectional view. This frictional clutch has now been in use several years in connection with endless rope haulage and has answered all that could be desired.

The friction wheel, *f*, is made of cast iron, and for a seven feet driving wheel has been made 30 in. diameter. The clip, *g*, and the sliding-box and arms, *q p*, are made of crucible cast steel. The friction wheel, *f*, is always kept well oiled, so that no grinding action takes place between the friction wheel and the clip, *g*, when the clutch is thrown into gear. The clutch is easily and quickly

thrown in or out of gear by four or five turns of a hand wheel. If the clutch be properly adjusted just to move the required load, there is no fear of breaking a rope by an excessive strain being put upon it in case of an accident with the trams on the roadway.

Several opportunities have been taken of mentioning this clutch arrangement during the progress of these articles, and the writer has gone further than merely approve the invention in writing, he has applied it to powerful hauling machinery. Although first introduced and applied to endless rope haulage working slowly and with no great load, its application is not confined to this particular method of haulage, nor is it even confined to haulage generally. Wherever machinery has to be thrown in and out of gear this friction clutch is available, and although it has been a chief cause of the success in the Clifton haulage arrangements, and will probably be most generally applied to haulage, the writer ventures to predict its extensive and successful adoption far from the Midlands, and to machinery both for haulage and many other kinds of work. It entirely dispenses with the old-fashioned clutch, where strain was inevitable and actual breakage very likely, and substitutes an arrangement easily worked, whereby the most powerful machinery with proper care can be thrown in or out of gear without producing any undue strain, and without any risk of smashing machinery. Figs. 210 and 211 show the hauling engines and gearing generally in plan and elevation.

The latter portion of this article has given a fair idea not so much of the Clifton haulage generally as of the most peculiar features, namely, the clip hook and the friction clutch, whilst the whole article has dealt generally with endless rope haulage of various kinds, and this brings our haulage chapters to a close. Without trying to be prolonged or prosy we have endeavoured to deal fairly and fully with the various systems, and without having shown any prejudice it will not have been difficult to discover that the very best system of haulage in the writer's opinion is the endless rope worked from the surface, the rope being under or over the tubs, as best suits the method of loading the tubs. Whilst spending a short time with his friend, Mr. C. E. Rhodes, of the Car House and Aldwarke Main

Collieries, Rotherham, the writer had some conversation with Mr. Rhodes about haulage—and few men are more qualified to advise upon any matter of mining or mining machinery. The collieries are almost models of arrangement, the hauling, winding, screening, ventilating, and other machinery being excellent, and Mr. Rhodes has come under public notice of late very prominently as having conducted at his own colliery the most elaborate and successful experiments with safety lamps that have ever been taken in hand, not even excepting the Royal Commission, which does seem in many respects to have been a disappointing tribunal. (The writer was bold enough to predict in the Preface to Second Edition of Volume I. of this work, that Mr. Ellis Lever's offer of a £500 prize would not produce a real safety lamp.) Mr. Rhodes was good enough to agree with the writer that driving haulage from the surface was right, and that generally the endless rope was the best, but in some cases where the output was large and the distance very great (perhaps several miles) he thought the tail rope would come off first best. Probably Mr. Rhodes is right, but such cases are and will be exceptional, therefore they tend to prove rather than disprove the rule in favour of endless rope.

Whilst at Aldwarke Main the writer was shown a comparatively new wheel (new then, not so new now), of which some thousands were in use, and for which there was a rapidly-increasing demand, and a description of which will not unfitly conclude this section of our remarks. These wheels are the invention of Mr. W. Eyre, of Messrs. John Brown and Co. Limited, Sheffield, and are shown in fig. 212. They are stamped out of plain discs of plate steel, the blanks being first flanged for the tread, and they are then punched and dished. Through the centre hole is driven a cast-steel bush, which is firmly riveted to the wheel body, and the wheels being chucked by their tread on the lathe, the hub is soon bored out, and the rail flange trimmed up, the result, when complete, being a neat, light, and strong wheel capable of rough wear.

In the case of fast wheels the collar of the axle and the wheel are riveted together, and the end of the axle is

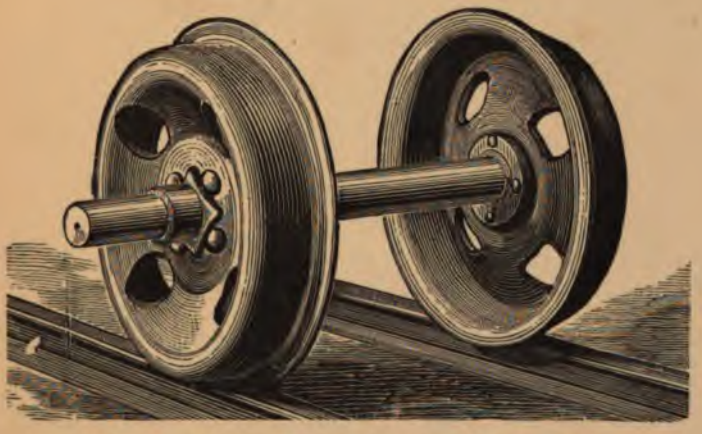
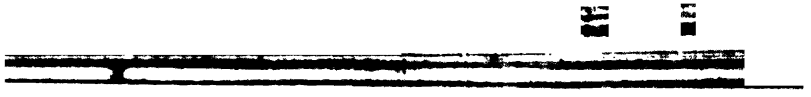


FIG. 212.—FORGED STEEL WHEELS—EYRE'S PATENT.

[*To face page* 292.]



also riveted over the wheel. The advantages claimed for these wheels are that absolute freedom from breakage is ensured, that the form of the wheels gives great elasticity combined with strength, and, further, that the wheel can be made lighter than any cast wheel. An objection was made at first that the large rounding on the outside of the "tread" was against keeping the wheels on the rails. This has since been remedied, and with advantage.

CHAPTER XXVI.

HAULAGE.—COMPOUND HAULING ENGINES.

Variety in Hauling Engines—Horizontal or Vertical—Single or Coupled—Geared or on First Motion—Similarity as regards being Non-condensing and working at Moderate Pressures — The System of Haulage largely determines the Class of Engine—For Quick Haulage the Engines should always be in Pairs—For Slow Haulage a Single Engine will answer—Piston Speed for Continuous Working Hauling Engines—Piston Speed in Intermittent Haulage—For Slow Haulage the Engine should be Geared—For Quick Haulage Engines on First Motion are best — Hauling Engines may work (1) Non-condensing and Non-expansive, (2) Non-condensing and Expansive, (3) Condensing and Non-expansive, (4) Condensing and Expansive—The usual Hauling Engine is Non-condensing and Non-expansive—Surface Engines might be Condensing and Expansive — Difficulty as to Condensing Arrangements underground — Extravagance of Non-condensing and Non-expansive Engines—Example to show that Expansion is Gain—In Theory there is no Limit to Gain from Expansion—In Practice there is a Limit—Why we have so little Expansion in the ordinary Haulage Engines — Machinery for the Intercolonial Coal-mining Company of Nova Scotia and Montreal—A Compound Hauling Engine—High Initial Pressure and High Ratio of Expansion—Walker Brothers, Engineers, of Pagefield Ironworks, Wigan—Specification of Engines—Cylinders and Pistons and Rods—Cross Heads—Motion Bars—Connecting Rods—Cranks—Eccentrics, and Rods, and Straps, and Reversing Links, Drums, Bearings, Framing, Friction Gear—Defects of usual Clutch Gear — Friction Gear of Mr. Henry Fisher, of Clifton Collieries, Nottingham — Joy's Valve Gear — Disadvantages of Eccentrics and Links—Advantages of Joy's Valve Gear —Sir William Siemens—Description of Joy's Gear—Compounding — What is a Compound Engine? — Two-Cylinder, Three-Cylinder, and Four-Cylinder Engines — Daniel Adamson—Expansion in Simple and Compound Engines — Advantages of Expansion in Compound Engines — Rule to Proportion the Cylinders of Compound Engines—The Receiver in Compound Engines — Its Object and Position — Advantages of a Large Receiver — Calculation as to Power of Compound Hauling Engine.

THE figures 213, 214, 215 represent side elevation, end elevation, and plan of compound hauling engines. The

figures 216 and 217 represent elevation and plan of Joy's valve gear as applied to horizontal engines.

There is considerable variety in engines for haulage, as regards their being horizontal or vertical, single or coupled, geared or on first motion; but there is a great similarity in their being non-condensing and practically non-expansive, and in working at moderately low pressures, seldom exceeding 60 lb., and very often not more than 45 lb. The vertical engine, as illustrated in previous chapters, has been popular in endless chain haulage, and where sufficient height is available such answers well enough, because no drums are required, and they occupy very little ground space. But probably, as in winding, the most popular is the horizontal engine, which has also been illustrated.

Whether engines shall be single or work in couples depends very much on the kind of haulage to which they are applied. If for quick running, such as direct haulage or tail-rope systems, where the speed of rope reaches ten miles an hour, then the engines virtually become winding on a smaller scale, and for such purposes engines working in pairs are far the best. For slow haulage, such as the endless chain and the endless rope, where the speed often does not exceed one mile an hour, and the average not more than two miles an hour, the engine works continuously, and one engine working alone probably answers as well as two coupled. The particular system of haulage also practically decides whether the engine shall be on first motion—that is, give its power to the rope direct from the crank shaft—or whether it shall be on second or third motion with gearing intervening. For an engine running continuously the piston speed should not exceed 250 feet per minute; and if we had endless haulage with chain or rope travelling at two miles an hour, with a wheel 5 ft. diameter and a stroke of 3 ft., we could arrive at the proportion of gearing.

Two miles an hour = 10,560 ft. per hour ÷ 60 = 176 ft. per minute; 5 ft. diameter = 15¾ ft. circumference; 176 ÷ 15¾ = about 11 revolutions per minute. With a piston speed of 250 ft. per minute, a stroke of 3 ft. would represent about 42 revolutions per minute, showing that in such a case the proportion of gearing would be about

4 to 1; and if the speed of the rope was less, and the diameter of the driving-wheel greater, then we should have a larger proportion in the spur gearing.

To work intermittently, as in direct or tail-rope haulage, we could allow a higher piston speed, which should not, however, exceed 400 ft. per minute. Suppose a drum 6 ft. diameter = about 19 ft. circumference, gave motion to a rope at a speed of 10 miles an hour = 52,800 ft. per hour ÷ 60 = 880 ft. per minute ÷ 19 = 46½ revolutions per minute. This 46½ revolutions would, if the stroke were 3 ft., represent a piston speed of 279 ft. per minute, and if the stroke were 4 ft., would represent 372 piston feet per minute. Generally speaking, then, we might say that for slow endless haulage our hauling engines should be geared, and work either single or coupled at a piston speed not exceeding 250 ft. per minute; and for quick intermittent haulage there should be a pair of engines working on first motion, the piston speed not to exceed 400 ft. per minute.

Now, how shall we work these hauling engines? (1.) Non-condensing and non-expansive, (2) non-condensing and expansive, (3) condensing and non-expansive, (4) condensing and expansive. Probably the great bulk of our hauling engines all over the mining districts will be found working non-condensing and almost non-expansive. If placed upon the surface there is no reason why they should not have all the advantages which both condensation and expansion will give, especially if continuous working, and even when working an intermittent haulage. Surely if we have shown in these chapters an efficient automatic expansion arrangement for winding engines, whose period of work rarely occupies one minute, we can apply such an arrangement to an engine whose shortest run will occupy a good many minutes. When placed underground the application of condensing arrangements is not so easy, the difficulty being in some cases the obtaining the needful water supply, and in all cases dealing with the water afterwards. We cannot, as in underground pumping engines, turn the exhaust into the suction, and whilst generating a vacuum pass the steam and water away together. The non-application of condensing arrangements operates seriously against economy, especially if

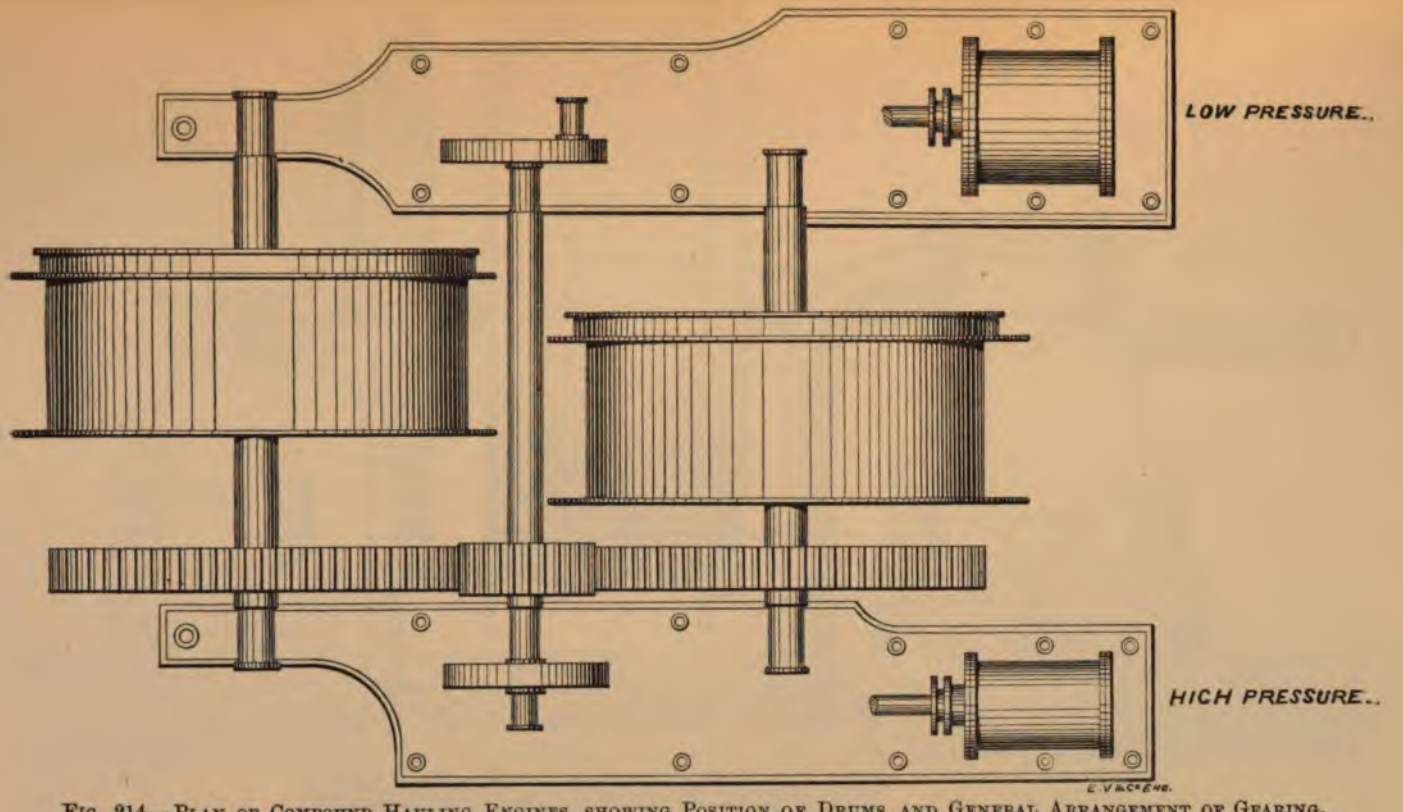


FIG. 214.—PLAN OF COMPOUND HAULING ENGINES, SHOWING POSITION OF DRUMS AND GENERAL ARRANGEMENT OF GEARING.

[*To face page* 296 (*b*).]

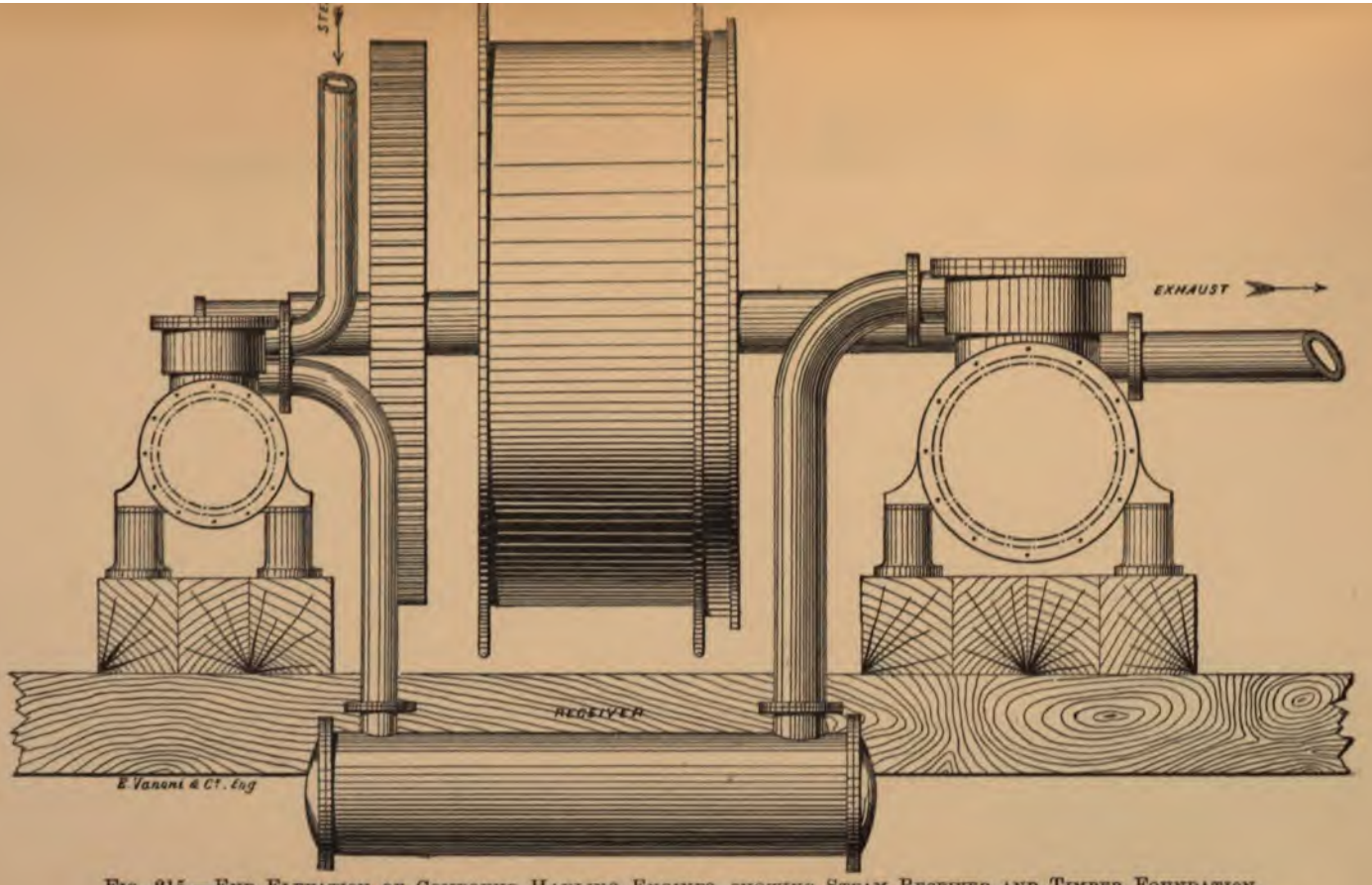
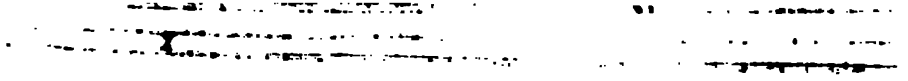


FIG. 215.—END ELEVATION OF COMPOUND HAULING ENGINES, SHOWING STEAM RECEIVER AND TIMBER FOUNDATION.

[*To face page* 296 (c).]





working at comparatively low pressures. Suppose we use steam at 120 lb. absolute, we cannot exhaust below 18 lb., that is 3 lb. above the atmosphere, therefore must lose 120 ÷ 18 = nearly 1-6th of the efficiency of the steam. If we use steam, which is more commonly the case, at 60 lb. absolute, then we lose 60 ÷ 18, nearly one-third of the efficiency, whereas if our condensation arrangements were anything like effective, and we attained, say, 12 lb. vacuum, which is not unusual, we should lose with 120 lb. initial absolute pressure only 120 ÷ 3 = 1-40th, and even with so low an initial absolute pressure as 60 lb. we should lose only 60 ÷ 3 = 1-20th. These simple figures show the desirability of condensing arrangements, which Watt so much appreciated, but they also show the great benefit of high-pressure steam, of which Watt was certainly not enamoured. We are not likely yet to see condensing appliances very generally adopted, either in winding or in haulage, but we may expect, and have a right to expect, a general adoption of expansion appliances. When we use steam non-expansively—that is, with full pressure of steam upon the piston all through the stroke, which is effected by having the communication between the boiler and the piston open during the entire stroke—we have exactly the same power in the steam at the end as the beginning, and as we cannot have used any of it if it all remains, we are actually discharging or exhausting twice in each stroke a cylinder full of steam which has actually done no work. The work has been done by fresh supplies of heat coming in from the boiler to take the place of that which has passed away in the shape of work.

Some able writers with more logic and high learning than accuracy have proved to their own satisfaction that expansion is not gain. We will not in this unpretentious practical work, written for working men by one of themselves, enter the very high preserves of learned argument, but we will suppose two cases—one in which we use non-expansively steam of 120 lb. absolute pressure, and one in which we have the same initial pressure and expand twelve times. In the first case we use each stroke, say, 12 lb. of steam, and have a uniform pressure of 120 lb. In the other we use each stroke 1 lb. of steam and obtain some-

thing over 30 lb. average pressure, so that with 1-12th of the steam we get one-fourth of the work, being a gain in this case of at least 3 to 1 in favour of expansion; and theoretically the higher the ratio of expansion the greater the gain. In practice, of course, there is a limit beyond which expansion ceases to be effective and becomes very expensive. Perhaps the great reasons why we know so little of expansion in our ordinary haulage arrangements are, first, the usual arrangements of eccentric and slide valve are not conducive to effective expansion, and the limit is narrow; second, the low pressures of steam limit the range of expansion; third, the single-cylinder engine affords little scope for expansion.

The figures accompanying this article illustrate a type of haulage engine which seems to overcome these several difficulties. The initial pressure high, viz., 150 lb., the ordinary valve motion is superseded, and we use the steam in two cylinders and obtain an expansion nine times; the initial steam pressure being 150 lb., that is, 165 lb. absolute, we exhaust at 18 lb., being 3 lb. above the atmosphere. The compound hauling engines shown in figs. 213, 214 and 215 have recently been constructed for the **Intercolonial Coal-mining Company, of Montreal, by Messrs. Walker Brothers,** of Pagefield Works, Wigan, who have a deservedly high reputation in the manufacture of all kinds of colliery machinery, and have probably not yet been got to work. The writer was honoured with the confidence of the company in representing their interests and superviseing the designing and watching the construction of the engines, and introduces them here as an example of hauling machinery which combines many novel features likely to become generally popular.

A general sketch was furnished by the engineer of the Intercolonial Company, and the following specification:—

Cylinders and Pistons and Rods.—To be two in number, one high-pressure 16 in. diameter, the other an expansion or compound or low-pressure cylinder 28 in. diameter by 2 ft. stroke, and to be so arranged that by lifting a valve high-pressure steam can be admitted into the low-pressure cylinder for the first few revolutions, as it is then the engine has its heaviest lift. To be of strong hard cast

iron, all wearing parts to be well fitted. Joints to be made steam-tight, metal and metal. Covers to have glands and stuffing-boxes, with neck and gland bushes of gun metal. All nuts to be case-hardened. Covers to have large relief valves to free cylinders of water. Suitable tallow cups to be supplied. Piston rod to be of steel. Piston packing to be of the latest approved kind.

Cross-Heads.—To be of steel or the best forged iron, with steel connecting pin, and to be so constructed as to take up slack as the slippers wear. The slippers to have a large bearing surface on motion bars.

Motion Bars.—To have a well or oil-receiver at each end of bottom bar. The bottom slippers to have a brass spring piece attached to each end to carry oil on bar. The top bars to be provided with suitable oil cups.

Connecting Rods.—To be of the best forged iron, properly fitted with straps, keys, and sett bolts and gun-metal bearings, and to have suitable oil cups.

Cranks.—To be of the disc form; to be made to balance connecting rods. The pins to be of steel.

Eccentric and Rods and Straps and Reversing Link.—The eccentric to be of good hard cast iron and made in halves, well secured together with bolts and cotters, and securely keyed on with keys sunk into the shaft. The straps to be bolted together; bolts to have nuts and lock nuts, and pin holes drilled through ends and split pins in.

Rods to be of forged iron, excepting the ends connecting to links. Steel pins to be fixed in to prevent wear in connecting rods. Reversing link to be of steel or forged iron, steel-faced and hardened. Pin-holes to be bushed with steel bushes ¼ in. thick, hardened, also fixed in, that they can be renewed at any time. Suspension link the same. Links to be balanced. (The adoption of Joy's valve gear made this paragraph null and void.)

Drums.—To be 8 ft. diameter when lagged with 4 in. thick of wood, and to be 3 ft. long. One drum to be in front of driving shaft, the other behind. The front drum to be 2 ft. 6 in. lower than the other, to allow the back



Collieries, Nottingham, had not long been introduced, but long enough to prove its efficiency. Mr. Fisher has rendered excellent service to the mining world by furnishing an elaborately illustrated paper on his hauling arrangements to the Chesterfield and Derbyshire Institute of Engineers. This friction gear has already been fully described in the chapter immediately preceding this, dealing with endless rope haulage. It will be sufficient to say here that the writer considers it the best friction gear ever applied to haulage. Drums or pulleys can be thrown in or out of action with the engines running at any speed and without strain upon the machinery or risk of breaking any of the parts. Consequently it was applied to these particular hauling engines.

Joy's Valve Gear.—After very careful consideration the now well known and very extensively applied Joy's valve gear was adopted in preference to the ordinary eccentric arrangement. The usual link motion has had its day, and whilst no doubt it has done good work in its time and overcome considerable difficulties half a century ago, was never more than an imperfect appliance. The eccentrics take up considerable room on the shaft, which, as for example, in the limited room on a locomotive crank shaft, is a serious matter where we want as much room as possible for bearings. The friction also which eccentrics generate is very great, in consequence of their very extensive circumferential surface. And as one eccentric is required for each direction of the engine, we have always an idle eccentric absorbing as much work as the active eccentric. The advantages claimed for this new valve gear are—(1) it may be applied wherever the link gear is applied, (2) it is simple, and, taking the best form of application, is less costly than the link gear; (3) it simplifies the construction of the engines; (4) the new gear is more correct; (5) the new gear is more accessible; (6) the complete gear is always in useful action; (7) overhauling for repairs and for taking up wear is more easily executed, and the gear is more easy to reverse. The inventor, Mr. David Joy, has devoted many years to this special work, and now sees it adopted on all sides. Sir William Siemens pronounced it "a perfect valve motion." Joy's valve gear obtains

the needful motion from the connecting rod, and is very simple in its arrangement. No eccentrics or links are needed, and the actuation of the valve is mathematically correct, and the lead remains constant whatever the position of the gear.

Figs. 216 and 217 show the application of Joy's valve gear to a horizontal engine, not the compound beating engine of which this chapter treats, but the principle is the same, and the explanation of the gear will be clearer than a figure from the compound engine.

In the connecting rod, from a point A, preferably about the middle, motion is imparted to a vibrating link, B, constrained at its lower end to move vertically by the radius rod, C. From a point D on this vibrating link horizontal motion is communicated to the lower end of a lever, E, from the upper end of which lever the motion is transmitted to the valve spindle by the link, G. The centre or fulcrum, F, of the lever, E, partakes also of the vertical movement of the connecting rod, to an equal extent to the amount of its vibration at the point, A; the centre, F, is for this purpose carried vertically in a slot, J, which is curved to a radius equal to the length of the link, G, connecting the lever, E, to the valve spindle. The slot itself is formed in a disc or sleeve, K, which is concentric with the centre, F, of the lever, E, at the moment when that lever is in the position given by the piston being at either end of the cylinder. This disc is capable of being partially rotated on its centre so as to incline the slot over to either side of the vertical by means of the worm and hand wheel, M, thereby causing the curved path traversed by the centre, F, of the lever, E, to cross the vertical centre line and diverge from it on either side as will. The forward or backward motion of the engine is governed by giving the slot this inclined position to one or other side of the vertical centre line: and the amount of expansion depends on the amount of the inclination, the exactly central or vertical position being "mid-gear." In that position steam is admitted at each end of the stroke to the amount only of the lead: and this is done exactly equally on each side of the centre line, the amount of lead being constant for forward and backward motion and for all degrees of expansion. Thus,

when the crank is set at the end of the stroke either way the centre, F, of the valve lever coincides with the centre of the slot, and therefore the slot may be moved over from forward to backward gear without affecting the valve at all.

It will be seen at a glance that if the lower end, D, of the lever, E, were attached directly to the point, A, on the connecting rod there would be imparted to the centre, F, of that lever an unequal vibration above and below the centre of the disc, K. The extent of inequality would be twice the versed sine of the arc described by the lower end, D, of the lever, E, and this would give an unequal port and unequal cut-off for the two ends of the stroke. But this error is corrected by attaching the lower end, D, of the lever, E, to the vibrating link, B, for while the point A on the connecting rod is performing a nearly true ellipse, the point D in the vibrating link, B, is moving in a figure like an ellipse bulged out at one side, and this irregularity is so set as to be equal in amount to the versed sine of the arc described by the lower end of the lever, E, thus correcting the above error and giving an equal travel to the centre, F, of the lever above and below the centre of the slot. At the same time the error introduced by the movement of the end of the valve link, G, is corrected by curving the slot, J, to a radius equal to the length of G. These two errors may, however, be set against each other, and a compromise may be made by attaching the end of the lever, E, direct to the connecting rod at A, and allowing the centre, F, to slide in a straight slot. By a just balancing against each other of the errors so produced, and by making the centre, F, of the lever, E, and the centre of the disc, K, to coincide at varying points in the travel of the former, a fair motion may be got for the forward gear of an overhead marine engine, giving a longer cut-off for the up-stroke than for the down-stroke. This is, of course, at the sacrifice of the backward gear, in which the reverse is the case, and the various degrees of expansion are between the two extreme conditions.

Referring again to the equalising of the traverse of the centre, F, of the lever, E, in the slot, J, the unequal traverse may be either under-corrected or over-corrected

have two cylinders—namely, a high pressure, which is smaller in diameter and into which the steam enters from the boiler, and a low pressure, which is larger, into which the steam passes after doing its work in the high pressure. Whether an engine is compound or not, if we have the same amount of steam and the same ratio of expansion, we get the same amount of effect. But if all the expansion takes place in one cylinder, say nine times, we have nine times as much strain upon all the parts of the engine commencing the stroke as ending it, whereas if we have two cylinders—the low pressure three times as large as the high pressure—and we cut off at one-third in the high pressure, we get three expansions there, and when the steam is liberated into the larger cylinder we get a three-fold expansion again, and as three times three are nine, we get a nine-fold expansion with only a variation of strain of 3 to 1, as compared with a variation of 9 to 1. Another unquestionable advantage is we can adapt the temperature of the cylinder to the temperature of the steam entering it. If we use steam at 165 lb. absolute and expand nine times in one cylinder, we have a variation in pressure from 165 to 18, being a variation in temperature from 365 to 222, whereas by having two cylinders, and only needing to expand three times in the high pressure cylinder, we have only a variation in pressure from 165 to 55, and in temperature from 365 to 287. To use our ordinary pressures of about 60 lb. absolute, compounding scarcely comes in, because without condensing appliances we cannot expand below 18 lb. absolute, which only allows about three expansions, and that we can manage in one cylinder.

There are one or two points in the matter of compounding which deserve attention. First, as regards the proportioning of the cylinders. Determine the initial and terminal pressures of steam. In our particular case we have 165 lb. initial, and as we want a nine-fold expansion the terminal pressure will be $165 \div 9 = 18\frac{1}{3}$. Then get the square root of the number of expansions. The square root of 9 is 3, and as the root is to the square, or as 3 is to 9, so must the area of the high pressure cylinder be to the area of the low pressure cylinder, that is as 3 to 9 or as 1 to 3. Then again as the root is to the square, so

maintained. Then, as regards the load the engines are capable, according to these calculations, of drawing. The piston travels 300 ft. per minute, and consequently the crank will travel 468 ft. per minute. The wheel gearing is 3 to 1, and the drums are 8 ft. diameter, whilst the stroke is 2 ft. Therefore the speed of the rope will be 468 ÷ 3 = 156 × 4 = 624 ft. per minute, being between 8 and 9 miles an hour. The speed of the rope, being practically double the speed of the piston, the power upon the rope will be half the power upon the piston. Therefore 200 × 70 = 14,000 × 2 = 28,000 ÷ 2 = 14,000 pounds available pull upon the hauling rope. Deducting one-third for frictional and general resistances, 14,000 − 4,666 = 9,334 pounds = a vertical load of 83⅓ cwt., and upon even so steep an inclination as 1 in 3 this would represent a load of 12½ tons running at an average speed of 8½ miles an hour. The above are merely approximate calculations, based upon a certain initial pressure and a certain piston speed, but they furnish some idea of the horse-power these compound hauling-engines are capable of and the load they would be equal to moving, and probably in actual work under the same conditions they will not fall short of these satisfactory results. We can safely assert that no ordinary system of hauling engines of the same dimensions could do such an amount of work, and certainly not with so small a consumption of steam. And lastly, we have the great advantage that although the initial pressure is so high as 150 lb., we are able to exhaust, at scarcely more than atmospheric pressure, which in the workings of a mine is advantageous.

In concluding the chapter we hope these compound hauling engines will do credit to their makers, Messrs. Walker Brothers, engineers, of Pagefield, Wigan, and give satisfaction to their owners, the Intercolonial Coal Mining Co., of Montreal and Nova Scotia.

CHAPTER XXVII.

HADFIELD'S STEEL CASTINGS FOR COLLIERY USE.

Cast Steel for Hauling and other Appliances—The Age of Bronze—The Age of Iron—The Age of Steel—Sheffield the Monarch of the Steel Industry—Armour Plates and Needles—Locomotives and Penknives—Wheels, Axles, Pedestals, Pulleys, and Rollers—Importance of Durability in Colliery Materials—Cast Iron is Treacherous—Requires Constant Renewal—Cast Steel almost Everlasting—Mr. Robert Hadfield, of the Hadfield's Steel Foundry Company, Sheffield—Popularity of the Hadfield Specialties all over the World—Description of the Hadfield Works—Toughness, Durability, Density, and Soundness essential Qualities of Good Steel Castings—Careful Analyses and Elaborate Mechanical Tests—High Temperature of Molten Steel—Difficulties of Casting—Allowance for Contraction—Annealing and Cleaning—Great Variety in Steel Castings—Weights from Several Pounds to Many Tons—Immense Collection of Patterns—Machinery for Finishing the more Elaborate Castings—Tub Wheels Fast upon the Axles—Importance of being made Secure—Hadfield's Method of Fastening Wheels fixed on by Hydraulic Pressure—Tub Wheels Loose upon their Axles—Importance of Efficient Oiling—Hadfield's Self-oiling Wheel arranged for Inside or Outside Bearings—The Advantages claimed for it—Injurious Effects of Bad Rollers and Pulleys upon Hauling Ropes—Advantages of the Steel Pulleys and Rollers—The Self-Oiling Roller Boxes—The Registered Angle Pulley and Frame for taking Ropes round Curves—Steel Castings at Blast Furnaces—Hadfield's Patent Manganese Steel—Hard, Tough, and Non-magnetic—Benjamin Huntsman and the Early Days of Steel—Robert Hadfield and Steel Castings—Useful Memoranda for Steel-users.

Whilst engaged upon the preceding chapters dealing with haulage, it has repeatedly been suggested that some reference should be made to the growing importance and increasing adoption of cast steel as a material for colliery purposes generally and for hauling appliances especially.

It was well said that the early times, dating far back through the centuries, formed the age of bronze, and that the last two or three hundred years, leading up to our own time, have been the age of iron. We have already well commenced—and ere many years have passed away iron will practically have become historic, as bronze has done, and we shall be living in—the age of steel.

Anxious to supplement one's own practical experience with that personal observation of actual processes essential to thorough knowledge, the writer has upon more than one occasion of late found himself in the great centre of industry, Sheffield, which although scarcely fair to look upon from an artistic point of view, is monarch of the steel trade, and whilst providing food for over 300,000 people, sends its products all over the globe. Sheffield, the noisy and dark-visaged city of steel, does everything with its special commodity that the skill of men can accomplish, from the massive armour plating, over 2 ft. in thickness, to coat the sides of our ships of war, and against which shot and shell hammer in vain, to the delicate needle plied by some fair hand, or from the locomotive engine and its thousands of miles of road, to the penknife for the pocket of the urchin enjoying his golden days at school.

But it is none of these we care so much about just now. We want to speak of wheels, axles, pedestals, pulleys, rollers, &c., so essential in colliery hauling operations. When we consider that in our mines we have more hundreds of tubs or wagons than we raise in hundreds of tons per day, and that in very many of our hauling arrangements, especially the systems we have so recently been describing, we require for good working a pulley or roller for each few yards of working way, we see at once the immense importance of a material which will be durable, and thus avoid the delay and expense inevitable with constant renewals.

Until a few years ago all wheels and all pulleys were of cast iron, a treacherous material at best, and liable to rapid wear. Fitted with this, the pulleys and the wheels would by accident, or wear, or both, require almost complete renewal each two or three years. In many collieries where very heavy work is experienced it is found neces-

sary to renew the wheels every nine or ten months, owing to the constant breakages, also that rollers and pulleys are often sawn through in as many weeks. This, of course, could not go on. Some other material was bound to take its place; such material is taking its place, and in a comparatively short time, judging from the effect already produced, cast steel will be triumphant, and cast iron, for such uses at any rate, pass out of existence.

Great difficulties have had to be overcome and many improvements made, and whilst admitting fully that many hands and many minds have been engaged in various parts of the Kingdom, it is only in the inevitable fitness of things that Sheffield should rule the roost. No man even here has done more than Mr. Hadfield, founder of the Hadfield's Steel Foundry Company and foundry which bears his name, and whose specialities are appreciated in every land.

The writer has been fortunate in some practical experience with these productions, and his correspondents at home and abroad being, for the most part, similar in this respect, he, whilst speaking in the highest terms of all makers aiming at excellence in this matter, will confine his remarks here to Hadfield's, being those he knows most about. He also feels fully justified in so doing, owing to the varied and long experience this firm have had, making steel castings their sole speciality since the founding of the business. The numerous awards at different "World's Fairs" are also a flattering testimonial to the high quality of their productions—viz., gold medal, Paris, 1878; gold medal, Melbourne, 1881; gold medal, Madrid, 1883; special diploma of honour and silver medal, Sydney, 1880; highest awards at smaller exhibitions in this country; also the highest award for steel castings at the Calcutta Exhibition this year—namely, first-class certificate and a silver medal.

The works, very properly somewhat kept from the vulgar gaze, are most complete and interesting to the privileged visitor, and have, on the occasion of more than one visit, afforded pleasure and instruction to the writer. Well-appointed establishments for every branch of the industry, divided into distinct departments, each super-

intended by efficient foremen, ensure an accuracy and excellence in manufacture not easy to be surpassed.

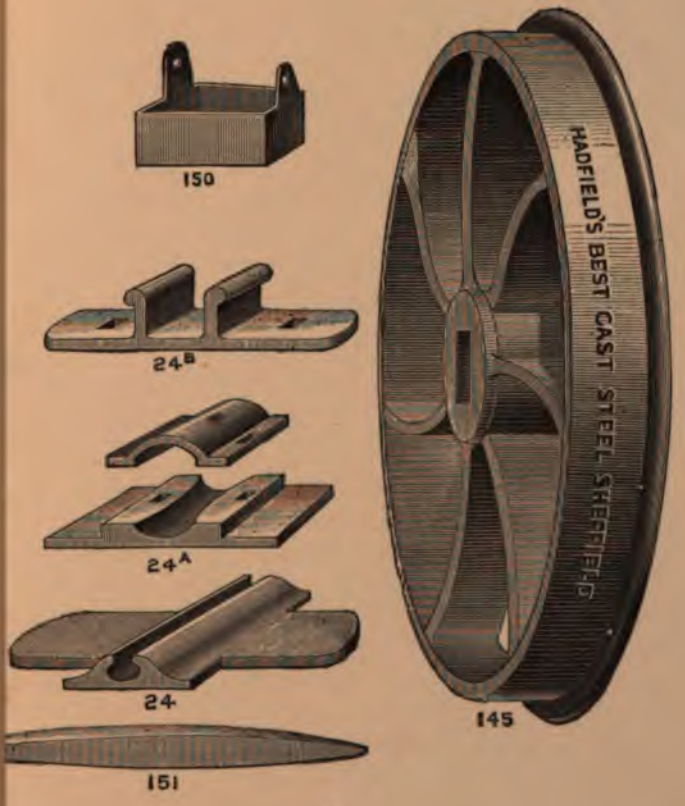
In addition to the well-equipped foundry, containing steam cranes capable of lifting fifteen to twenty tons at once, the Hadfield's Steel Foundry Company have a first-class machine shop, fitted with the latest modern improvements, and capable of turning out all kinds of finished work. This shop contains several overhead rope travelling cranes on the newest principles, and such is their simplicity that any ordinary unskilled labourer without any assistance can lift and take from one part of the shop to another loads of ten tons with perfect ease and safety; also planing, drilling, and slotting machines, hydraulic and steam presses, steam hammers, 3 and 10-ton portable steam cranes, lathes of all sizes up to the massive tool weighing close upon 30 tons. This will give a rough idea of the plant necessary to the production of steel castings, and show that Messrs. Hadfield have fully laid themselves out to do the work well and efficiently. The electric light is being thoroughly tested here, and, so far, has been found efficient and superior to the old systems.

It is no part of our present purpose to write a description of the process whereby the steel itself is manufactured (that may come at some future time when a kindred work to this is written of the engineering of iron and steel); we suppose the cast steel ready to our hands, and the quality of this cast steel makes all the difference between success and failure throughout the manufacture. There is "steel, and steel," and on the quality we use will depend the properties of toughness, durability, density and soundness, for which Hadfields have obtained that to which we all aspire, a good name. This has of course only been arrived at by great study and application, and by making use of all the latest improvements and appliances. The "rule of thumb" is not considered the only guide at these works, for we were much pleased to see a well-appointed laboratory, so that chemical tests and analyses can at once be brought to bear. Thus being able to test all raw material as well as the finished products enables this firm to make a thorough uniform material with almost absolute certainty, and thus avoid so many

of the mishaps which, without such appliances were inevitable, and have brought many well intentioned makers to grief.

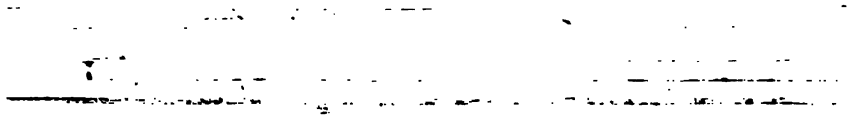
Mechanical tests are also very freely used, and comprise over two hundred different specimens by Her Majesty's Government, Kirkaldy, Professor Huntington, Professor Kennedy, &c., for tensile, elongation, compression, bending and drop tests. To give some idea of what has been accomplished with unhammered steel castings, as high as 40 tons to the square inch tensile strain with 20 per cent. elongation has been obtained, and with their special mild hammered steel a tensile strain of 31 tons to the square inch, with 30 per cent. elongation, a somewhat startling advance on the steel of even seven or eight years back. Also a special hard quality of unhammered steel castings has given as much as 65 tons per square inch tensile strain with 6 per cent. elongation, approaching within a very close distance of Whitworth's expensive compressed steel, a wonderful result, seeing this material had never had any mechanical treatment whatever, but was simply in its cast state, of course properly annealed and passed through their special processes.

The steel castings as they leave the moulds do not appear so smooth as cast iron, but when it is borne in mind that the temperature of ordinary molten cast metal is about 2,000 degs. Fahr. against molten cast steel, 3,000 degs., it will be readily seen what greatly increased difficulties steel founders have to contend with in this point. Naturally, cooling down from this intense heat means greater contraction; consequently, all patterns for steel castings have to be made $\frac{1}{4}$ in. per foot larger than the finished castings are required to be—that is, double the amount for cast iron. Messrs. Hadfield pointed out a large hydraulic cylinder, 22 ft. in length, the mould for which had actually to be 22 ft. 6 in., thus having to contract 6 in. when set as compared with its molten state. It will therefore be seen what a serious obstacle this increased contraction is to deal with, and unless the material is very equally proportioned the castings are liable to pull themselves in pieces when cooling. Annealing extending over a considerable period gives the castings a toughness and density and nature, and the



gie Wheel. 76. Mining Wheels and Axles, Outside Bearings.
24, 24A, 24B. Cage Guides. 145. Contractors' Wagon Wheel.

[*To face page* 312.]



particles an unstrained connection with each other, which equips them to meet the various forces to which they will be opposed. Then—as regards smaller articles—comes the cleaning, simple and thorough, a mere rapid motion of a number of miscellaneous articles within a revolving drum, ensuring by their contact with each other a freeing from sand and clearing of rough places. The noise in this department is, perhaps, not pleasant, but it was extraordinary to notice the severe tests to which the castings are subjected in this revolving machine, being rolled about for more than an hour together. Similar articles in cast iron would have been smashed to pieces, thus showing, even at this early stage, the great difference between the two materials.

Steel castings of every description are to be seen in course of manufacture, comprising those for railways, tramways, hydraulic and other engines, agricultural and general castings, machine moulded gearing, &c., ranging from a few pounds in weight up to 6½ and 7 tons each. Those castings, forming parts of machinery that have to be turned and bored, then pass on for manufacture in the various lathe, planing and slotting, and drilling machines before referred to. But for general work, our wheels, rollers, pulleys, and pedestals are now practically ready for being fitted up. There is scarcely anything in machinery but can be made of this material, and Hadfields' large works show how extensive its application has become. Their pattern stores alone contain over 15,000 different models of parts of machinery, &c. We, however, deal in this chapter simply with colliery appliances. The accompanying engraving (fig. 218) shows in all fulness the varieties of wheels and axles, rollers, pulleys, cage-guides, pedestals, &c., produced under this process. For greater convenience the various articles shown in the several figures have numbers corresponding with the numbers in the makers' establishment, and the reference describes each article.

In very many of our collieries the system is that the tub wheels are fast upon their axles, and when fast wheels are used it is important they should not come loose. The patent system adopted here makes it an impossibility for wheels to work loose on their axles, a matter which has

caused great annoyance and complaint in colliery working, and by this patent system of Hadfield's alone over a million wheels have been fitted up, apart from wheels bored and keyed on, wedged on, &c., &c., a fact which, we think, speaks for itself, as many systems tried in collieries have proved total failures; in fact, we saw at Messrs. Hadfield's works several samples of these systems which have been applied to colliery wheels and axles, and have been returned to them totally useless, and as scrap. Fig. 219 shows sections of wheels and axles fitted together for inside and outside bearings. The arrangement is that the round portion of the axle, *i.e.*, the body itself, enters the wheel a certain distance with its full strength, by this means avoiding the weakening which attends all axles with sharp collars fitted against the wheel, &c. The wheels are forced on their axles by powerful machinery capable of exerting a pressure of 30 tons (this pressure varying according to the diameter of wheel and axle), after which, in the case of inside bearings, the end is securely rivetted over. The axle ends being forged larger than the hole in wheel when the axle is forced by the pressure and passes through the said hole, so close is the fit that it takes off shavings from the inside of wheel boss, thus proving and ensuring two purely metallic bearings or surfaces, and entirely preventing the possibility of grease or oil working in between the two and causing the wheels to come loose.

In other colliery districts, especially where large tubs, and consequently large wheels are used, loose wheels are often required, and with these the all-important matter is oiling—important, because of the enormously increased load which unoiled wheels generate, and important because an unoiled bearing wears itself rapidly away. And we do not want spasmodic oiling, which, flooding the bearing for a few minutes, leaves it practically without oil for hours together. But we want continuous and sufficient lubrication. This is effected by having the boss of the wheel hollow, and within this hollow part oil is placed, reaching about up to the under side of the axle. The axle does not run in the well of oil, but the revolution constantly throws up sufficient drops, which, falling upon the bearing, keep it well lubricated. By these





means a bearing is kept free from dirt, and a weekly or fortnightly charging for oil suffices. So far we have dealt with wheels, and, in addition to the difficulty about looseness and oiling, these must be such as will not wear away rapidly and not break. The best proof of this is that wheels put on more than a dozen years ago are running yet, and breakages are an absolute rarity. One set fell down a shaft nearly 500 yards deep, a short time ago, and although the wheels were of a light pattern, weighing only 17 lb. each—notwithstanding this excessively severe test there was not even the slightest appearance of crack or fracture. The writer has seen wheels, not selected, but chosen at hazard from a heap, placed upon an anvil cold and hammered into the form of a polygon without breaking, and there is no difficulty in then hammering such a distorted wheel back into proper working shape. One firm in South Yorkshire, before adopting steel wheels and axles, and in order to carefully test the merits of different systems of cast steel, malleable and other wheels, kept a careful record of breakages, &c. The cast-iron wheels, of course, rapidly broke; two of the better ones of the other kinds gave 10 per cent. breakages, whilst not a single one of Hadfield's wheels and axles gave way. This firm, therefore, entirely adopted this system, and have now over 20,000 wheels and axles upon this patent system in daily use. One set of 9-in. wheels has been running constantly day and night for five years, has run 41,000 miles, carried 10,000 tons of coal, has made nearly 100,000,000 revolutions, and only worn $\frac{1}{8}$ in. on the tread. A 30-in. wheel has run 11,000 miles, carried 33,000 tons of earth, and is only worn $\frac{1}{8}$ in. on the tread.

The patent self-oiling steel wheel shown amongst the figures has had claimed for it (and has stood all tests) the following advantages:—

1st. Not more than one-third of the oil or grease is required as compared with the ordinary method.

2nd. The bearings never become dry, the revolving of the wheel leads out the oil as required, and immediately the tub or wagon stops the lubricator ceases its action, thus causing no waste. The result of all this is less wear

and tear and great saving in haulage power caused by there being so much less friction.

3rd. No waste of grease can occur, no matter in what position the wagon may be placed when discharging its contents, even if upside down, and when the wagons are not in use it is impossible for any grease to escape, as it is all stored below the outlet.

4th. When once these wheels have been charged with grease, which can be done by any inexperienced person, they do not require any attention or re-greasing whatever for several weeks or even months afterwards, in proportion to the distance travelled.

5th. These wheels are readily fixed to any description of iron or wood tub or wagon now in use, whether the wheels are upon the inside or outside of the frame.

6th. They are simple in construction, have no detail, and are not liable to get out of order.

7th. They possess great strength, durability, and extreme lightness.

The rollers and pulleys are well illustrated in the various figures; they have on many grounds become exceedingly popular, and the reason is not far to seek.

An important item in the renewal of mining plant is the cost of wire ropes for inclines, endless ropes, and other systems of haulage power. The real cause of this expense is often not that the rope itself has been inferior, but has been severely punished by being "sawn" over heavy, unequally thick, and lob-sided rollers and pulleys, which frequently remain fixed, heavy side downwards, until they are completely sawn through by the constant friction of the passing rope, thus acting similarly to an endless band saw, consequently rapidly destroying the skin, fibre, and strands of the said rope, and requiring increased haulage power. Steel rollers and pulleys are claimed to have the following advantages:—

1st. They are nearly one-half lighter than cast iron.

2nd. Being better made, equally balanced, and never lob-sided, the instant the hauling rope touches them they readily revolve, thus avoiding all grinding or sawing by the rope, and consequently save power and prolong life of ropes.



FIG. 220.—HADFIELD'S STEEL CASTINGS.

Reference to Illustrations:—55A. Self-oiling Single Flanged Wheel.
74. Special Steel Axle with Cotters and Markers.
72A. Self-oiling Double Flanged Wheel.
75. Special Steel Axle with Solid Collars.
34A, 34B, 35A. Light Pedestals.
66A. Spanner.

[*To face page* 316.]

[*Copyright.*
All rights reserved.]

3rd. They are much stronger, and cannot be broken by ordinary means, say by the sudden passing of chains over them, such as frequently connect the rope to the tub or wagon, or hang loose from the end of passing tubs or wagons.

4. They have great durability, and will outlast ten or twelve cast iron pulleys or rollers.

5th. By reducing wear and tear to a minimum they effect a great saving in working expenses.

6th. Cast-steel spindles of special good quality are carefully fitted in these rollers, and add greatly to their life.

Hadfields have in stock over 1,100 different-sized wheel patterns, from 6 to 36 in. diameter, of varying widths of tread, flanges, bosses, &c., and yet different styles are wanted almost daily. The reason is, we colliery people all have different ways of doing our work. In some special cases there is nothing we can lay our hands upon that meets our requirements; then a special design is inevitable. But generally we should be able to find an appliance ready to our hand, actually better fitted to our wants (having borne the test of experience) than anything we could suggest.

The methods of securing the wheels upon their shafts give the most excellent results. For small wheels the system has already been described. For larger wheels they are forced on the axles by powerful hydraulic machinery, exerting a pressure of 30 to 120 tons, varying according to the diameter of wheel and axle, after which the axles, if necessary, may be securely riveted. This severe test ensures every wheel being perfect before leaving the works, and the machine secures truth as well as exactness of gauge. And so absolute is the accuracy in the workmanship that there is absolute interchangeability—a point which is considered of the highest importance in some quarters, but is scarcely an essential with these steel wheels, because they neither break nor come loose. Experiments were, however, specially made in a wheel and axle, which were taken apart and re-fitted —the wheel on different axles and the axle in different wheels—no less than five times—thus fully proving their interchangeability.

The self-oiling roller boxes (Hadfield's registered pattern), also well shown amongst the illustrations, are very simple, very effective, and consequently are becoming very popular. They are easily fixed, only need oiling about once in several weeks, are very free from friction, work easily, and when a pulley wants changing—which is not often, as the spindle on which it is mounted is also steel—it can be lifted out in a few moments and another dropped in its place. Of course the whole fabric—namely, roller, spindle, and frame—are of cast steel.

Also the "registered" angle pulley and frame is of great advantage in taking ropes round curves. It is very simple in construction, has no parts liable to get out of order, and can be easily greased. The pulleys are interchangeable and can be renewed at any time. This article is also constructed entirely of cast steel.

Much, very much more might be said, but the foregoing is sufficient to show what has been and is being done to introduce a material for colliery purposes which, whilst almost everlasting in point of wear, gives a maximum of strength with a minimum of weight, and avoids the manifold troubles with which ordinary colliery appliances are so much identified. Blast furnaces, too, which have found cast iron wheels for bogies and for barrows a daily source of accident, keeping a good sized foundry going for renewals, have by the adoption of steel wheels shown that accidents are quite preventable, and renewals absolutely avoided.

The makers of steel castings have worked hard and have exercised never-ceasing ingenuity; they have conquered many prejudices and overcome many difficulties, and now the sun of prosperity, or, at any rate, success, shines upon them.

The writer was shown some specimens of a remarkable new material discovered by this firm, known as "Hadfield's patent manganese steel." This steel possesses the special qualities of hardness and toughness combined, and an axe made of same, in the rough, never hardened or tempered, had chopped through ½ in. square iron. One of the curious things connected with this steel is that it is non-magnetic, and, as the *Engineer* of February 8, 1884, remarks, "it is rather curious that the properties herein found should only

be now found, and after finding a steel that is at the same time very hard, very tough, not attracted by the magnet and with considerable elongation, we may next expect anything to turn up to upset one's ideas as to the characteristics of steely materials."

The name of Hadfield is inseparably identified with the industry by early and long connection and extensive operations. A production in wheels and axles alone of thousands per week, and an actual output of nearly one and three-quarter millions, combined with the reputation for high-class workmanship acknowledged all over the world, is a higher and more substantial form of testimonial than any words which this feeble pen can write.

But the writer bears his personal testimony, gathered from his own practical experience, and the corroboration of his wide circle of friends and connections, and ventures to predict that the steel castings with which Hadfield's Steel Foundry Company and hosts of friendly competitors are honourably associated, will in colliery hauling appliances replace everything for which they can possibly be adapted.

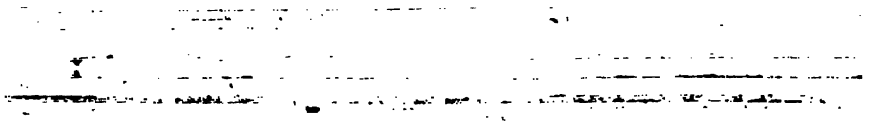
Even now the only reluctance is in consequence of the first cost, but that will not long bar the way. The most inveterate opponent of modern improvements and innovation will in the inevitable course of things be made to see that an article which costs say four times as much and wears twenty times as long, and to which accidents are unknown, is far away the cheapest.

Sheffield, and more particularly that portion of it known then, and known still, as Attercliffe, was made famous in the eighteenth century by the operations of Benjamin Huntsman, one of the creators of the steel industry. Hadfield has given this locality an increased reputation in a similar kind of industry, more than a century later, and by the combination of rare practical ability and eminent inventive genius, has provided for colliery proprietors at home and abroad an excellent material, has founded a large and successful business, and has made a name known and respected in all parts of the world where steel castings have been brought into use.

Figures 218, 219, 220, 221, 222 illustrate the various specialities in steel referred to in this chapter.

The following very practical and very easily understood memoranda have been specially drawn up for the information of present and intending users of steel.

1. There is nothing so dear as inferior cheap steel.
2. Over-heated steel tells its own tale.
3. The quality of the iron used in steel-making determines its value.
4. The higher the quality of the iron the better the steel.
5. Consumers of steel should state the purpose steel is required for; the steel maker will then state what temper of steel is most suitable.
6. Phosphor and sulphur are enemies to steel.
7. Pure fuel is essential to heating or working steel.
8. The peculiarities and treatment of steel require special skill and experience.
9. The hardening of steel is regulated by its percentage of carbon heating it lower or higher, according as it contains more or less carbon. The safest course is to harden at the lowest heat that will give the required hardness.
10. Hardening cracks more frequently result from irregular heating than from defects in the steel.
11. All steel requiring hardening should be heated by a slow soaking heat, and never heated higher than what is sufficient to take the temper.



CHAPTER XXVIII.

AIR-COMPRESSING MACHINERY.

Variety in Types of Air-compressing Machinery—Divided Opinion as to its Use—There are Operations for which it is Specially Adapted—Comparisons as against Hydraulic Power and Steam—Advantages of Compressed Air—Underground Locomotives—General Description of a Modern Air-compressing Engine—Its Action—Maximum Theoretic Effect of Air-compressing Engines—Average Results in Practice—Cost of the Machinery—Why is the Useful Effect so Low?—Loss of Power by Liberation of Heat—Loss of Power by Liberated Heat Expanding the Compressed Air in the Cylinder—Loss by Limit of Expansion—Proposals to Prevent these Losses—Mr. E. A. Cowper—Sir William Siemens—These Proposals have not been carried out in Colliery Machinery—Early Air-compressing Machines—Experiments in Scotland—Description of the Engine—Valves of Brass and of Gutta Percha—Air-compressing Machinery in Wales—Liberation of Heat during Compression—Formation of Ice during Expansion—Power for Coal-cutting and Tunnelling and Rock-boring Machines—Defectiveness of Air-compressing Engine having no Circular Motion—Colliery Proprietors and Inventors—A Good Coal-cutter still Wanted—Mr. William Daniel, and Messrs. John Fowler and Co., Leeds—Their Air-compressing Machinery in South Wales—Description of the Engines—The Inlet and Outlet Valves—Speed of the Pistons—Water Jackets and Air-receiver—Construction of Exhaust Passages to prevent Formation of Ice—Experiments to show Useful Effect at Various Pressures—Importance of Indicating the Air Cylinder—Mr. Firth—Mr. C. Cochrane—Mr. E. A. Cowper—Sir Frederick Bramwell's Comparison between Compressed Air and Water Power—Mr. John J. Geach, of Bristol—Mechanical Appliances at the Severn Tunnel Railway—Description of the Air-compressing Engines—Herr Wendelstein, of Lucerne, and the St. Gothard Tunnel—Description of the Air-compressors and the Turbines that worked them—The Sturgeon High-speed Air-compressor—Description of the Engine—Peculiarity in Action of the Inlet Valves—Arrangement for Regulating the Speed—Defects of an ordinary Single Air-Compressor—Importance of Effective Valves—Sufficient Area—

Ease and Quickness of Action—Messrs. Walker Brothers, Pagefield, Wigan—Their Excellence in Air-compressing Machinery—Clearance in Air-cylinders—The Air-receiver—Its Twofold Advantage—Mr. D. K. Clark's Manual for Engineers—Experiments on the Resistance of Air through Long Pipes—Loss of Pressure and Leakage of Air at the Mount Cenis Tunnel—The Efficiency of Air-compressing Engines—Efficiency less for High Pressures—Mr. Pickard on the Efficiency of Compressed Air—Effect of Moisture on Air—Conclusion.

DURING the progress of these chapters, both those previously published as Volume I. and those which this chapter completes as Volume II., repeated reference has been made to the use of compressed air, and in this our concluding chapter we purpose dealing exclusively with that subject.

With regard to this, as with most other classes of machinery for colliery purposes, there is considerable variety in the manufacture, and there is also a divided opinion as to its use. Some mining engineers will not have compressed air at all, and others use nothing else underground. Probably the correct thing lies between the two opinions, and whilst there are operations for which it is specially adapted, it cannot be recommended for general adoption. The means of transmitting motive power that we have as against it are hydraulic power and steam power.

The circumstances under which water pressure can be utilised are exceptional, because under ordinary circumstances the work we could possibly do with water would be considerably less than the work we should have to do to send the water back. We have shown some exceptional cases in which water can be used with advantage. As regards steam power, where it can be applied there is nothing in our day and generation that will at all compare with it on the ground of economy. But in many cases, we may say the majority of cases, it is impracticable underground, being not only a nuisance, but even a danger. Compressed air is not only not a nuisance or a danger, but such slight effect as it has is beneficial upon the workings and upon the ventilation. It can be applied to work an engine at any point of the mine, either near the shaft or miles away, and for working coal-cutting

machines or tunnelling machines it stands practically alone. Considerable success has also attended its application to locomotives underground, and a good many such are now in operation, the best probably being these now working in the North of England coalfield under the patent of Lishman and Young. The engine simply carries a certain reservoir of compressed air capable of performing a certain amount of work.

It will not be necessary to present many illustrations to explain the construction and action of a good modern air-compressing engine, as both are not difficult to thoroughly understand. We have a horizontal steam engine, with crank and fly-wheel complete. The piston of the steam cylinder is prolonged through the back cylinder cover, and has another piston working in another cylinder behind the steam cylinder. This we call the air cylinder, which takes air in behind the piston and forces it out of the cylinder in front of the piston. The air is drawn in at atmospheric pressure and compressed to about 45 lbs. above the atmosphere, that being found by experience to give about the best results in working. What we do, therefore, in each single stroke of the engine is to take in a cylinder-full of air at atmospheric pressure, which, of course, represents no work, and we have to raise the pressure on the other side from nothing to 45, or, in absolute measure, from 15 to 60, and in doing so we lessen, or should lessen, its bulk proportionately. Now, looking at the matter simply and theoretically, if we could, in using the compressed air, simply expand it down to the atmospheric pressure we should get back all the work expended in compressing it. So that allowing something for resistance of machinery, we should get 80 or 90 per cent. useful effect; and if we could manage this everybody would use compressed air. But the very highest authorities place the theoretic useful effect of compressed air at 50 per cent., and the highest practical results do not average more than 25 per cent. We have to add to this low useful effect the not inconsiderable expense of the air-compressing engines themselves. So that in the face of facts like these—namely, expensive plant, which would matter little if that were all, but a very low useful effect, meaning a consumption in fuel of at least three times as much as if using steam—there is

no wonder proprietors and managers think seriously before adopting it.

An interesting point arises here: Why is the useful effect so low? First of all, the compression of the air liberates a large amount of heat, which passes away, and this considerable loss of heat represents exactly that loss in work. Second, during the compression the air becomes heated, so much so that what should be 2 cubic feet becomes 3 cubic feet, which would matter nothing if it remained at that bulk and could be used. But immediately it leaves the cylinder it reduces to 2 cubic feet, and whilst we have done the work of compression upon 3 cubic feet, we get work only out of 2 cubic feet. Third, we do not get much expansion out of compressed air, and that is an additional loss. It will not be difficult to understand from this why the efficiency is so low. Of course, the questions arise: Are these losses avoidable? Can we avoid the loss of heat? Can we prevent the great rise in temperature causing increase in bulk? Can we use the compressed air expansively?

Some years ago an ex-president of the Institution of Mechanical Engineers, Mr. Cowper, designed the alterations in a pair of ordinary blast-furnace blowing engines to adapt them for compressing air to 45 lb. The air cylinders were reduced from 50 in. to 20 in., and, in addition to being surrounded with cold water externally, an internal jet of spray was provided, which met the air during compression. The result, in working, did not justify the elaborate details of the designer.

Sir William Siemens, during the discussion at which Mr. Cowper had described what he had been doing, said he was very strongly impressed with the vital importance of avoiding steam in a mine, surcharged, as the mine already was, with heat, and the advantages of compressed air, which, being rendered by expansion so much colder than the prevailing temperature of the mine, was the very medium required. Some experiments which he had made proved to him that in the ordinary mode of transmitting power by compressing air, cooling that air, and then letting it expand again, the attainable limit of useful effect was about 50 per cent. of the power exerted in the compression. The remedy for the great loss arising from

the heat expanding the air was a simple enough one, and consisted in injecting cold water in the form of spray into the compressing cylinder in sufficient quantity to keep the temperature practically uniform throughout the stroke. Then, in expanding the air to do work, the difficulty of getting rid of the ice formed in the passages of the expanding cylinder might be altogether surmounted if water were injected into that cylinder at the temperature of 80 or 90 degs. commonly existing at the bottom of a coal mine. This water imparting its heat to the expanding air would prevent the formation of ice, and would produce precisely the same advantage as that obtained in the compressing cylinder by the injection of water, and these two savings together would very materially alter the result obtained in percentage of useful effect. The most perfect arrangement, indeed, if it could be carried out, would be to take the very same water which had been injected into the compressing cylinder and inject it again into the expanding cylinder, so that the heat taken from the air during its compression should be restored to it during its expansion. By that means, if the quantity of water injected were such as to keep the temperature practically uniform throughout the stroke, the whole of the loss at present arising from the heating and cooling of the air would be avoided, and there would be no loss of power beyond that due to the friction of the machinery and pipes. This, of course, was a very excellent proposal made some ten years ago, and had Sir William Siemens—whose loss to the world seems greater as time goes on—devoted his great genius and practical skill to its development we should now probably have air-compressing machinery working to more advantage. But so far as the writer knows, it has not even been tried anywhere, and, as a matter of fact, the usual air-compressing machinery of to-day possesses no appliance whereby cold water injected into the compressing cylinder or warm water injected into the expanding cylinder. We have to deal with them, therefore, with the defects pointed out strong upon them, and, judged in that light, can have no hesitation in pronouncing even the best of them not economical arrangements for transmission of power. And we have so many good practical engineers who make and

who use air-compressing engines, that it is reasonable to assume that there are good grounds for not having adopted the suggested improvements we have named. But admitting all the defects incidental to compressed air, we might aggravate them by bad machinery and bad appliances, and we might minimise them with good machinery and good appliances.

We shall now to some slight extent trace the progress and development of this transmitter of power. The earliest air-compressing engine, as shown in fig. 223, of which the writer finds a good illustrated record is one erected at a Scotch colliery as far back as 1850, and was intended to overcome the difficulty of providing for underground winding and pumping at a distance of half-a-mile from the main shaft. A steam-boiler was inadmissible, and the distance was considered too great to convey steam from the surface. Water-power was first contemplated, but it was afterwards decided to make use of compressed air supplied by a compressing steam engine at the surface, and conveyed down by a pipe to work an engine at the top of the second shaft, the discharged air being thrown into the workings to aid in the ventilation of the mine. The plan was carried out, and the air conveyed in a pipe 10 in. in diameter. The engine was on the beam principle, having the steam cylinder at one end of the beam, the crank ar the other end of the beam, and two single-acting air-compressors intermediate. The steam cylinder was 15 in. diameter, with a stroke of 3 feet, and the two air-compressors were each 21 in. diameter, with a stroke of 18 inches, and they alternately delivered the compressed air into a central reservoir, from which it passed into the main pipe. The piston rods of the compressors passed out below, where the stuffing-boxes were not exposed to the pressure of the compressed air, and they were worked with cross-heads sliding in vertical guides by means of side rods from the beam. The air-compressors were fitted with ball valves, of which there were three sets to each compressor, each set consisting of 44 brass balls, 2 in. diameter, arranged in three concentric rings, the balls being confined by separate cages to a lift of half-an-inch. In consequence of the high pressure of the air, amounting to 30 lb. per square inch (!) provision was made for leakage through the valves by a stratum of

water constantly covering the piston valves and the delivery and inlet valves. A small pump 3 in. diameter and 10 in. stroke was employed to supply water for this purpose, and delivered it into the central reservoir, from which it flowed through small pipes into each of the air-pumps during the period of their downward strokes, the quantity of water admitted being regulated. The surplus water was discharged at each upward stroke through the delivery valves, and flowed over the top into the central reservoir, keeping the delivery valves also covered with water. In this way the compressed air was entirely discharged, and there was no loss of power from expansion of air behind the piston at the beginning of the downward stroke. The level of the water in the central reservoir was regulated by means of a gauge glass at the side. Any leakage of water past the piston valves and piston escaped through the suction or inlet valves, and was carried off by a waste pipe fitted to the casing of the air-compressors. The compressor-barrels were lined with brass to prevent corrosion, and the pistons were also faced with brass, and were made without any packing, being merely turned a good fit to the cylinders. After six years' continuous day-and-night work no repairs or even adjustment were found necessary. The usual speed of the engine was about 25 revolutions per minute, which means a piston speed in steam cylinder of 150 feet per minute, and in the compressors of 75 feet per minute. The usual pressure of steam was 18 lb. and of air about 30 lb. The pressure of air at the lower engine, distant half-a-mile from the compressors, was only 1 lb. less than at the compressors. The absorption of heat on the sudden liberation of the compressed air from the lower engine at the discharge of each stroke caused so great a degree of cold that in winter the engine was often stopped by the formation of ice in the cylinder and in the exhaust pipe.

The designer of the engine said the most serious difficulty that had been anticipated when the apparatus was first designed was the considerable amount of heat that would be developed in the compression of the air, and the water had been employed originally for the double purpose of carrying off the heat and serving as a non-elastic medium for filling up the interstices among the valves,

whereby the whole amount of the air which was introduced above the valves was sure to be expelled onwards, thus securing the full value of the power exerted in the compression, and for these purposes it had proved wholly efficient. The temperature of the air in the main column varied from 90 degs. to 140 degs., depending on the velocity of the working of the engine and the state of the atmosphere; and if it had not been for the use of the water, the engine, it was considered, would have been a failure in attempting to compress the air to 30 lb. pressure per square inch, as the calculated temperature resulting from that amount of compression would have been somewhere near the melting point of tin. The three sets of valves were adopted to secure the greatest action from the compressors; the lower suction valves—namely, those in the bottom cylinder covers—were originally intended to be of gutta percha, to offer less resistance to the air entering, so as to allow the atmospheric pressure as nearly as possible to obtain in the lower part of the compressor when the piston was rising; on the descent of the piston the pressure accumulated to raise the weight of the brass valves in the piston.

Brass suction valves were, however, employed, on account of the difficulty of getting spheres of gutta percha of suitable description at the time the engine was constructed; but no doubt was entertained as to the superiority of gutta percha valves for the purpose.

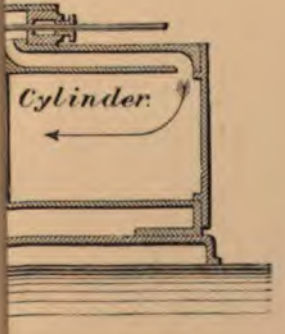
It was stated as the result of experiments that air at a pressure of 10 lb. per square inch was cooled down to 37 degs. temperature on expanding suddenly.

The very slight loss of pressure in travelling half-a-mile might be attributed to (1) the weight of the column in the main shaft, 176 yards deep, and (2) to the large main 10 in. diameter for conveying the air. Figs. 222 and 223 illustrate the general design of the engine and the arrangement of valves.

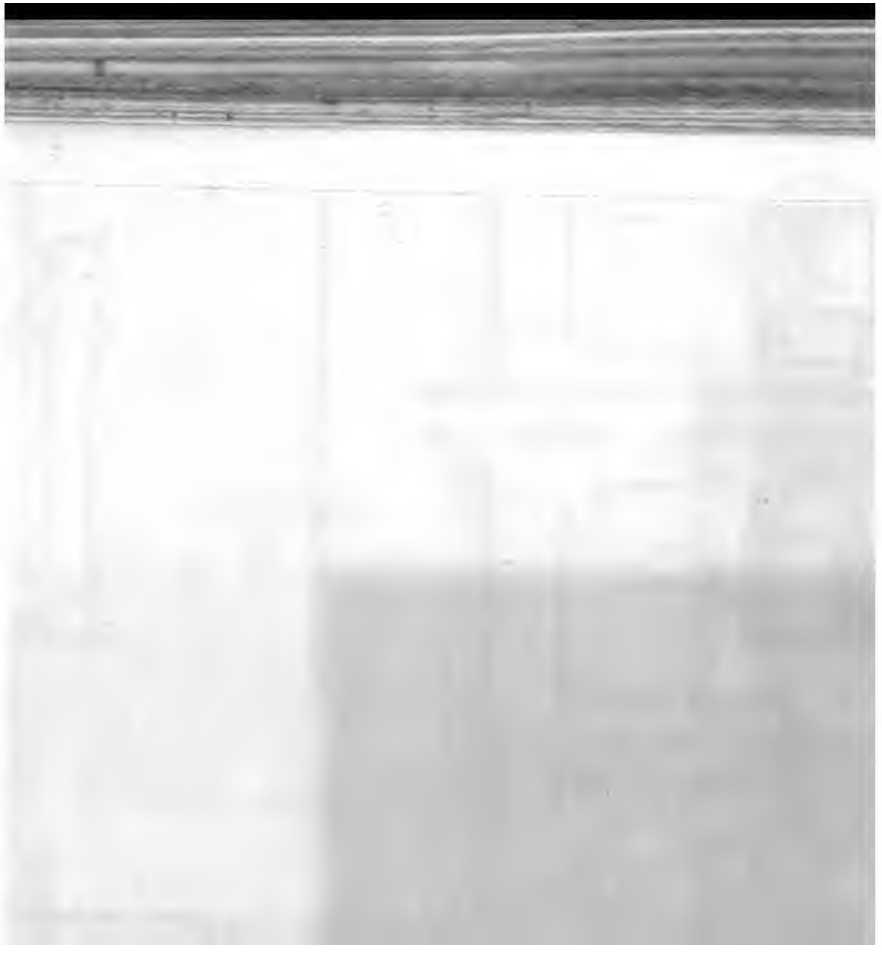
In 1864 a Welsh firm of engineers introduced a coal-cutting machine and an air-compressing engine, shown on fig. 224, to provide the necessary air. The engine was intended to work half-a-dozen coal-cutting machines, and consisted of two cylinders, one the steam and the other the air cylinder, fixed horizontally on the same bed plate,



ARRANGEMENT OF SPHERICAL CLACKS
N OF AIR-COMPRESSING ENGINE.



[*To face page* 328.]



the piston rod of the steam cylinder being directly attached to the piston rod of the air cylinder. The steam cylinder was 16½ in. diameter and 3½ ft. stroke, and the air cylinder the same. The air cylinder was surrounded by water, to keep it cool. The compressed air passed through the delivery valves into the pipes which led into the mine. The inlet valves were fixed on the side of the air cylinder, and were similar to the delivery valves. The slide valve of the steam cylinder was worked by a tappet, as there was no crank or fly-wheel to the engine. Some interesting facts were noted in connection with this engine. Air which at the atmospheric pressure had a temperature of 32 degs. would be raised to 110 degs. by being compressed to 30 lb. per square inch, and at 120 lb. per square inch the temperature would be raised to 450 degs.

The great losses of power in air-compressing engines, said the inventor of this engine, arise from leakage and friction in the air pipes and the mechanical power lost in the form of heat when the air is compressed. The loss from friction and leakage need not be great; good joints will avoid the one, and large pipes reduce the other; but the loss from heat is very great. The cylinder in which the air is compressed gets so hot that it is necessary to keep it surrounded with water, the temperature increasing with the pressure to which the air is compressed; and, on the other hand, when the compressed air has done its work, and is allowed to escape, a degree of cold is produced which freezes any moisture that there may be in the exhaust passages. By the compression of the air its capacity for heat becomes diminished, consequently a portion of the latent heat already contained in it at its natural pressure is developed in the form of sensible heat, and this is absorbed by the cylinder and the surrounding water. The air itself does not get sensibly hotter, since only its capacity for heat is changed by the compression, while the excess of heat developed by its compression is rapidly absorbed by the surrounding metallic surfaces which conduct it away. (This is hardly so in actual practice. The air itself does become very sensibly hotter, hence a great loss of power, and various methods referred to in this chapter have been applied with more or less success to prevent the air itself becoming hotter). When

this air has done its work and expands again to its original pressure, its original capacity for heat returns, and the quantity of heat then contained in it not being sufficient for maintaining the same temperature in its expanded form, it consequently draws heat from the surrounding atmosphere, thus producing cold. The amount of heat thus absorbed in the act of expansion is the exact equivalent of that which is developed during compression, but the heat developed during compression being lost by conduction, the amount of power equivalent to it is also lost. Fig. 224 shows the air-compressing engine just described, and the writer's first experience of air-compressing machinery, now near upon twenty years ago, was in connection with it. It was in use for several months, providing power for various kinds of coal-cutting machines, none of which came off very successfully, and to work a Penrice tunnelling machine, which was also a failure, and for the Diamond rock-boring, which was entirely successful.

As to the engine itself, the results could hardly have been worse. There was no expansion in the engine, the type making it practically impossible in the absence of any crank and fly-wheel, and with the air pressure gradually increasing as the stroke of the steam piston was made. Sometimes a full stroke was made, but very often an incomplete one; the valves were exceedingly defective in their action, and scarcely a day passed without a breakage somewhere. The engine and an exact fellow were absolutely impossible air-compressing engines, and are now, in a modified form, doing good service as colliery winding engines.

It is often said, and by none more so than inventors, that colliery proprietors will not adopt new appliances, and that, consequently, neither do inventors receive proper encouragement and appreciation and reward, nor do proprietors lessen expense and increase efficiency, as they might do. There are such people, no doubt, but the writer can testify that no class are more anxious to adopt any real improvement. The real fact is that so many inventions are worthless, and so many so-called improvements simply lead on to ruinous expense, that, no doubt, here and there a good man's efforts are not appreciated and a real improvement not recognised.



periments in connection with this particular
ssing machine and its attendant coal-cutting
ling machinery could be reckoned in thousands
and the results were *nil*. Twenty years have
ıce then, and, as we shall see presently, we
ıced in air-compressing, but have we made
ress in coal-cutting? Where is the coal-
ıchine even yet that in the majority of mines
ıl cheaper than by manual labour?

Mr. William Daniel, of Messrs. John Fowler
eeds, read a paper on "Air-compressing Ma-
which for matter and illustrations, and the
elicited, form the very best description of
f machinery ever published. We present some
ıtrations on figs. 225, 226, 227, 228, 229, 230,

gines were coupled together at right angles,
4 in. steam and 40 in. air cylinders, the stroke
the steam at a pressure of 70 lb. per square
? at quarter-stroke and the air compressed to
quare inch above the atmosphere. The steam
exhaust valves were ordinary Cornish equi-
ınd 9 in. diameter respectively. The inlet and
ıs of the air-compressing cylinders are shown
, 228, 229, 230, 231, 232. The inlet valves
t iron, with leather flaps, and there were three
each cylinder cover. The two outlet valves
in the cylinder cover, and were of brass, with
1¼ in. long, inclined at an angle of 30 degs. to
indle. Valves made of vulcanised india-rubber,
alves with common short-mitred and flat faces
but none of them were found to answer so
se shown in figs. 229 and 230. The engines
ın average piston speed of 240 feet per minute,
ı indicated horse-power of 482. The regulator
ıet to admit sufficient steam for driving them
ıd against the air-pressure of 40 lb., and they
ıelf-governing. The air cylinders had water
n at the top, and the air was forced into the
ıich was 30 ft. long and 5 ft. diameter. These
nsmitted power to a considerable number of
gines underground, and by a simple method of

arranging the exhaust orifice in these hauling engines the trouble previously experienced from the formation of ice, owing to the sudden expansion of the compressed air, was entirely avoided; the air was simply exhausted above and below, so that any ice which might form chipped off and fell through. Elaborate experiments were made to obtain the useful effect, with the following results:—

Air-pressure	40 lb.	—	gave useful	effect	25·8	per cent.
,,	34	,,	,,	,,	27·1	,,
,,	28½	,,	,,	,,	28·5	,,
,,	24	,,	,,	,,	34·9	,,
,,	19	,,	,,	,,	45·8	,,

Owing to the lower temperature generated at lower pressures, the experiments showed a larger percentage of useful effect as the air-pressure diminished.

The useful effect obtained from the use of compressed air at 40 lb. pressure was ascertained to be 25 per cent. of the power developed in the steam cylinder when working with 28 lb. steam in the cylinder continued for nearly seven-eighths of the stroke, and the percentage of useful effect would be materially increased by the use of 70 lb. steam cut off at quarter-stroke. During the discussion Mr. Daniel said the experiments he had made showed the great importance of frequently indicating the air-compressing cylinder to see that the valves were in proper working order. One experiment showed that the outlet valves were not properly constructed and that the springs closing them were too heavy; another showed the inlet valves to be out of order, because there was a vacuum of 3 lb. throughout the whole length of the stroke, showing either that the valves were not large enough or that the springs upon them were too strong.

In the discussion Mr. Firth, of coal-cutting celebrity, said, with regard to the formation of ice in the exhaust passages of machines worked by compressed air, he had found great difficulty from that cause in the early use of coal-cutting machines, the ports having been made too small; and it had been continually necessary to stop the working for half-a-minute at a time until the ice was melted. But by making the ports somewhat larger this

difficulty had now been almost entirely avoided, and there was now hardly ever any stoppage of the machine on that account.

Mr. C. Cochrane, referring to the loss arising from clearance at the ends of the stroke in air-compressing cylinders, mentioned that in the United States he had seen a pair of double-acting air-compressing engines coupled together with a short stroke of about 12 in., and having such a wash of water as to get rid of the clearance. The water was supplied from a chamber above the compressing cylinders, which formed the compressed air reservoir, and contained also some water, and the water was driven up into it at the end of the stroke so as to fill up the entire clearance space, by which means a perfect delivery of the whole of the air into the reservoir was obtained. Any excess of water supplied from the reservoir into each end of the cylinders was driven back into the reservoirs above.

Mr. Cowper said: For getting rid of ice formed in machinery worked by compressed air the use of large valves and large passages was a simple and effective plan. The cooling effect was in the expanding air, and any moisture in it would be turned into ice; consequently, if the exhaust air were allowed a very free discharge, so that it could come out with a sudden blast, it would take with it any ice that might be formed. A very simple mode of warming the cylinder of an underground air engine sufficiently to prevent any formation of ice would be to cast it with a series of radiating rings, or fins, on the outside, on the principle of the "gill" stove; these would effectually take up the warmth from the atmosphere in the mine and keep up the temperature of the cylinder sufficiently. The plan of air-compressors acting upon what might be called the "see-saw" principle had been used. A horizontal pump was employed, having a solid piston, with double-cupped leathers, working in a cylinder filled with water, and from each end of which rose a vertical chamber, with the inlet and outlet valves on the top. The motion of the piston caused the water to rise and fall alternately in the end chambers, and every particle of the air compressed in them at each stroke was expelled through the delivery valves without

any clearance space being left. There was a constant small supply of water to replenish the cylinder, which was thus always kept cool.

A pair of air-compressing cylinders that he had put up, 22½ in. diameter and 44 in. stroke, had vertical conical valves, with very small seats, and kept to their seats by springs very nicely adjusted; they moved so freely under a very slight force that they required a little friction putting on them to act as a slight drag and prevent them from dancing. They were opened by the air itself lifting them up to a stop. (These were the air-compressing engines already referred to in this chapter. In practice they were not a success.)

The President (Sir F. Bramwell) said the subject of air-compressing machinery suggested a consideration of the relative loss from friction in transmitting power by the medium of water or by that of air. It was frequently urged that there must be less loss in the transmission of power by air than by water, on account of the diminished friction of air; but although it was true as an abstract fact that there was less friction in the passage of air through pipes than arose from the flow of water through them, yet in any practical application, taking into account the difference in the pressures that would be employed in the two cases, this was not true. For with air the maximum useful pressure was about 40 lb. per inch; with water, 700 lb. might be assumed as a standard working pressure. Taking air at 40 lb. pressure and water at 700 lb., it was clear that in order to get an equal power out of an engine it would be necessary to use seventeen-and-a-half times as great a bulk of air as of water, and the velocity of the air through the pipes would have to be seventeen-and-a-half times as great as the water through the same pipes. Hence, provided the density of the air and water were the same, the skin friction, being as the square of the velocity, would be 306 times that with water; and as there was also seventeen-and-a-half times greater bulk to deliver, the power required to overcome the velocity would be as the cube of the velocity, or 5,359 times the power required with water. But the friction varies directly as the density; and air at 40 lb. pressure above the atmosphere,

being about 220 times as light as water, the foregoing figures had to be divided by 220, which gave as the practical result 1·4 times greater friction and twenty-four times greater loss of power with air than with water. This was the result with pipes of the same size; but it was evident that by increasing the diameter of the pipes used for air-transmission, and thereby reducing the velocity, the relative loss of power from friction would be reduced to a very large extent. It was thus seen that in practice there was far more loss of power in transmission of power by air than by water.

This conclusion, however, did not by any means imply that air was an improper medium to be used in a coal pit. On the contrary, there were so many cogent reasons in favour of its employment that the question of economy became one of minor importance.

Mr. John J. Geach, of Bristol, in a paper "On the Mechanical Appliances used in the Construction of the Heading under the Severn for the Severn Tunnel Railway in 1877," gives some particulars of the air-compressing machinery there used.

At first the air was pumped into the receiver by a pair of inverted single-acting cylinders 12 in. by 15 in.; a trunk, closed with a valve on the upper end worked in each cylinder, the trunks being driven by connecting rods from two opposite cranks on one shaft, on which a pulley 5 ft. diameter and a fly-wheel were fixed. The pulley was counter-balanced, but it was soon found that the belt, although 8 in. broad and double, would not stand the work, consequently a vertical engine, with 9½ in. by 18 in. cylinder, was coupled on at right angles to the cranks of the air-pump. This worked fairly well, but the delivery and also the inlet valve gave much trouble by breaking and sticking up. Another air-pump and engine were then considered requisite to avoid any delays, keeping the old one as a stand-by. This was made intentionally larger than the immediate requirements, and supplied sufficient air at a slow speed. The air and steam cylinders were each 13 in. by 18 in., mounted vertical on two similar standards, and coupled to the crank shaft at right angles to each other. The air cylinder was so made that if anything went wrong with

the valves at either end of the cylinder, the defective cover and valves could be taken off, and the cylinder worked single-acting. There were two inlet openings for air, which was intended to be forced into the cylinder by a ram, so as always to charge it fully for each stroke; also two outlets coupled to a 4-in. pipe leading to the air-receiver. The receiver was 28 ft. and 5 ft. diameter, formerly an egg-ended boiler, and was usually kept nearly half full of water to cool the air during compression in the cylinder. The receiver was fitted with water gauge, pressure gauge, and safety valves, and a 2-inch pipe was coupled to it, leading down the shaft and to the face of the heading. The inlet and outlet valves of the air-pump were of brass, arranged four in each cover, so as to give the least clearance. They worked well, not cutting or otherwise getting out of order. Their weight was balanced by springs. The air cylinder was jacketed with water to keep it cool, but the jets of water injected were found to keep the cylinder, &c., cool enough without the use of the jacket. At each end of the cylinder a small ball clack is screwed into the casting, and these clacks are coupled to the lower part of the air-receiver by a copper pipe $\frac{3}{8}$-in. bore. These small clacks were so arranged that when the pressure in the air-receiver was greater than that in the cylinder a jet of water was injected, and thus the air was kept sufficiently cool. The air and water were carried on together to the air-receiver, where the air parted with nearly all its water. The receiver was filled half-way up every week, and that quantity of water did not lower more than six inches during the six days' work, the water being continually circulated, heated, and cooled through the air-cylinder and receiver. The piston of the air-cylinder was hollow, and kept filled with water through small holes in the top, and the water had access to the circumference of the piston to keep the rubbing surfaces lubricated in working. These air-compressors had to work the rock drills. The steam pressure employed was from 60 lb. to 80 lb. per square inch, cut off at about half-stroke; and the steam cylinder being coupled at right angles to the air-cylinder, the air was readily compressed up to 60 lb. or 70 lb. per square inch. The mean pressure in the air-cylinder was

not equal to that in the steam cylinder, because the air was taken in only at atmospheric pressure, even supposing the air cylinder was completely filled at the beginning of each stroke. As the stroke proceeded the pressure rose, the maximum pressure of 60 lb. or 70 lb. being only reached in the latter part of the stroke.

The speed of the air-compressor to deliver the required quantity of air varied considerably with the state of repair it was in, the average speed being about twenty revolutions per minute for supplying two drills; the air cylinders and pistons were found to wear much more rapidly than the steam cylinders, owing to the water and the air combined and to the dirt that got in; on this account the quantity of air discharged could not be calculated from the speed of the compressor, and could only be ascertained by actual measurement. There had not been found any trouble from the valves at all. The arrangement for charging the inlet openings with air by means of a blowing fan driven by the engine had not been found necessary; the machine appeared to take in plenty of air unaided.

In January 1883, Herr Wendelstein, of Lucerne, gave an interesting description of the mechanical appliances used in making the St. Gothard Tunnel, in which air-compressors played an important part, and as the motive power at both ends of the tunnel was furnished by the streams in the neighbourhood the question of economy scarcely came in. The water worked turbines, and the turbines worked the air-compressors. These were placed three in a set, of the Collodon type, and were made with interchangeable parts in order to reduce the time of repair to a minimum. The compressors and turbines were mounted, the compressors lying horizontally and the turbines being vertical. Above each turbine was a horizontal shaft carrying a bevel wheel which geared into a bevel pinion on a vertical shaft, and at each end of this shaft, and lineable with it, was another horizontal shaft having three cranks at 120 degs., which were attached, connecting rods from the three compressing cylinders. And these shafts were so connected by clutch gear that one or more sets of compressors could be worked as desired. The compressors were double-acting, and

placed parallel to each other. The piston rods passed through both ends of the cylinders. The diameter of the cylinders was 19 in. and the stroke 17 in., and the mean piston speed was 266 feet per minute. The position of the cranks gave a uniform motion without the employment of a governor. To cool the air during compression two methods were adopted. In the first place the cylinder was provided with a jacket, in which there was a continual circulation of cold water. The piston rod was also made hollow, and carried within it a copper water-tube 1½ in. diameter. This tube, which was open at each end, had near the middle a collar outside it of diameter equal to the bore of the rod, which it therefore closed. On each side of this collar the rod was pierced with three holes communicating with the interior of the piston, thus putting in communication the annular spaces within the piston rod on either side of the collar. A small fixed tube passed through a stuffing-box into the copper water tube. The cold water entered through the small fixed tube, returned from the other end outside the copper tube, passed through the interior of the piston to get from one side to the other of the collar already named, and returns to another pipe, whence it is conducted away through a flexible bore. By this means the surfaces in contact with the compressed air, both inside and out, are kept always cool, whatever the speed; and if the air be dry no other cooling arrangement is necessary. Secondly, there are two spray-injectors fixed at each end of the cylinder. The water for these is filtered first through a sand filter, and then through a wire sieve to get rid of the fine granite silt found in Alpine water, and so prevent wear of packings, &c. The filtered water arrives at compressors through pipes, passes through the air-bends, is compressed by a pump attached to the cross-head of the compressor, and is forced as fine spray into the cylinder. The volume of the injected water is less than the $\frac{1}{1000}$th part of the air used in the same period. It passes with the compressed air through the exhaust and through pipes to the large air-receivers, where the water is deposited. Each set of three compressors delivered 141 cubic feet per minute compressed to eight atmospheres. The piston-packing was formed of two bronze rings, with a space

between them, which is filled with water through a hole from the inside of the piston. This water forms a liquid packing, and at the same time cools the walls of the cylinders during the stroke. Some of it also escapes past the rings, and, entering the cylinder, takes the place of the spray in cooling the compressed air; for this purpose it was raised to a higher pressure when necessary by a special pump.

The Sturgeon air-compressor, shown on figs. 233 and 234, is somewhat peculiar amongst this class of machinery, by reason of its high speed, the idea being that more work can be done with a smaller engine, and it is contended that a higher useful effect also is obtained.

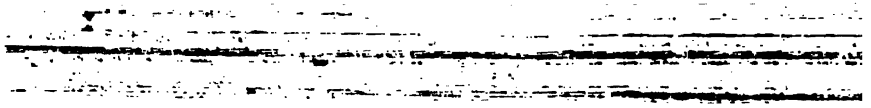
The inlet valves are quite different in their mode of operation from inlet valves generally. The usual arrangement is that they are placed in the cylinder covers, and are opened by the vacuum and closed by the pressure. In the Sturgeon engine they actually form part of the stuffing-box upon the piston rod, and are made to open and close by their grip of the rod compelling them to move. This method hardly strikes one as being an improvement, but the results in practice have been good. Neither would a very high speed appear to be desirable for a continuous-working air-compressing engine where the amount of work being done was practically uniform, a moderate piston speed being desirable in air cylinders as in steam cylinders. But just as we can do well enough with a considerable speed in winding engines and hauling engines which work intermittently and for no lengthened period, so an air-compressing engine may do well enough running even at a very high speed, if such high speed does not need to be continued long. The best that could be said would be that under exceptional circumstances the Sturgeon high-speed air-compressor would probably give a good account of itself, but for general colliery use is certainly not the best type of air-compressor.

There is an ingenious arrangement which seems to take the place of a governor and works successfully. On the fly-wheel shaft there is an eccentric, which, by communication with a combination of levers, actuates the valve of the steam cylinder in such a manner as to lengthen or shorten the travel according as more or less work is being

done, and more or less air is being required. But the same result would be obtained by an effective governor arrangement operating upon the throttle valve. There is one exceedingly good point in the Sturgeon compressor, which is a considerable improvement upon the usual single engine. Customarily the air and steam cylinders are in line, one piston-rod answering for both pistons, but by placing the pistons in connection with separate cranks fixed at right angles, we make the steam piston most effective, that is its crank is at full throw when the work upon the air piston is greatest, namely, when the stroke is about being completed. This principle ought to be applied to all single air compressing engines, otherwise the possible expansion of the steam is very limited. The Sturgeon compressor is a very compact piece of machinery, having the receiver between the two cylinders, and a good fly-wheel upon each side. It runs even at high speeds with much steadiness, and very little foundation is required, it being so well balanced and the strains so equally distributed. Fig. 233 shows Sturgeon compressor in plan. Fig. 234 shows valve arrangement at one end of cylinder.

As has just been remarked in describing the Sturgeon engine, one defect in the ordinary single air-compressing engine was that as the steam was expanding the air was being compressed, that is, when the work to be done was increasing the power to do it was decreasing. With a pair of engines working coupled and at right angles and a fly-wheel, this defect scarcely existed, but in a single engine it did seem requisite to so arrange the connection with the crank that when most work had to be done most power was available. In the working of the engine it was essential that the valves should be effective, namely, that they all should have sufficient area. The inlet valves should open immediately the stroke commenced, otherwise a partial vacuum would form, causing drag upon the piston, and should close immediately the return stroke commenced, otherwise air would be discharged into the atmosphere and a portion of each stroke wasted. The outlet valves should open immediately the piston pressure equals the receiver pressure, and should close immediately it becomes less, otherwise on the one hand we are putting undue work upon the engine, and, on the other hand, we





do work and then lose it. This means that we must have nicely adjusted valves, capacious, and easy and quick in action. And so important is this that the difference in valves often makes the difference between good and bad engines. The valves of air compressing engines have occupied more time and exercised greater ingenuity than any other, or even all other parts of air compressing machinery. Those of Messrs. Walker, of the Pagefield Ironworks, Wigan, are deservedly the most popular, because they are the best valves working. Acting successfully on the very numerous engines of their own make, they have been and are being largely applied to engines by other makers. We may have defective engines even with good valves. We cannot have even moderately good engines with bad valves. Then comes the matter of clearance. Even in a steam engine we now endeavour to make the clearance capacity small, because the steam it contains does little or no work. But in air compressing engines it is matter of vital importance. Let us see what we do, having drawn air from the atmosphere. Three-fourths of the stroke are occupied in compressing the air to the pressure at which we purpose using it—and theoretically all this reduced bulk should go into the receiver. If it does not do so we have been compressing so much air, expending so much work, to no useful purpose. It was said once during a discussion that this was no loss, because it exerted power the other way upon the piston. This is absolute nonsense, because the moment the return stroke begins the inlet valves open, making a communication between the piston and the atmosphere, and this highly compressed air at once falls to atmospheric pressure. To show the importance of this small clearance, if the cylinder is 4 ft. long and the clearance 3 in., the loss from this alone is 25 per cent., whereas with a clearance of $\frac{1}{8}$ in. the loss would only be 1 per cent. Then comes the receiver, into which the air is delivered. If we had no receiver, and delivered air simply into a pipe, the pressure would rise and fall injuriously, and we should have great friction generated by the rapid passage of air in the pipes. A large receiver gives us a nice storehouse in which the pressure remains practically uniform. A receiver should also be placed

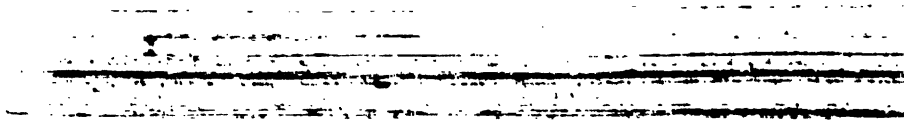
close to every engine worked by compressed air to always afford a good supply for the engines to draw from. It answers another purpose. Moisture more or less always passes into the compressing cylinder with the air, and if not drained off would have an injurious influence in the expanding cylinder; it falls to the bottom of the receiver and can periodically be drawn off. In bad arrangements great loss will result from leakages at the joints of the pipes, and more care is necessary than with steam pipes, because a leakage of steam is seen, whereas a leakage of air is not. There ought to be no trouble in making good joints at first, and such will give little or no trouble afterwards.

An interesting feature in compressed air is the heat at the compressing cylinder, and the intense cold at the expanding cylinder.

The compression liberates heat, which raises the temperature of the air that has been compressed. Then, having done its work and being discharged into the atmosphere at its original pressure, the re-expanded air is deficient in heat exactly what was pressed out of it, and wanting this the temperature is so low that moisture and water in connection with it become snow and ice.

There need be no hesitation in recording here that Messrs. Walker Brothers, Engineers, of Pagefield Ironworks, Wigan, have devoted more time to the study of the application of compressed air for colliery purposes than any other firm either at home or abroad. They have also made more air-compressing engines, and have attained greater distinction than any other firm. Fig. 235 illustrates a large pair of their engines constructed for the Linby Collieries, in Nottinghamshire, managed by Mr. Henry Lewis.

The steam cylinders are 40 in. diameter by 6 ft. stroke, and the air cylinders are 42 in. diameter also by 6 ft. stroke. The fly wheel, which is not shown in the figure weighs 25 tons. The engines are now supplying compressed air to all the machinery underground. The weight of coals hauled along the various roads in the mine is over 2,000 tons per day. Fig. 236 represents a pair of smaller air compressing engines by the same makers, the cylinders being 18 in. diameter. The engines are supplied with





expansion valves fitted with suitable expansion gear for varying the cut-off when required. Apparatus for condensing the steam is also supplied, and these condensers can be arranged to work either horizontally or vertically. The modern air compressors of this firm have the valve arrangements such that the air is conducted from the cylinder below the floor line. The outlet valves are also fixed in the cylinder covers. The following is given as an outline specification of Messrs. Walker's air-compressing engines.

The cylinders are cast of strong close-grained metal, as hard as can be readily bored and planed. The covers are turned and polished. All the glands are bushed with brass. The valves are on the slide principle, and are fitted with variable expansion gear when required. The air cylinders are fixed on a line with the steam cylinders. Each air cylinder is partially encased with metal plates, forming a cistern for cold water, to prevent overheating. The air cylinders and valves are so arranged that practically all the compressed air is expelled from the cylinders. The air cylinders are fitted with Walker's patent valves. The pistons are of cast iron, with packing rings of similar metal. The piston rods are of Bessemer steel. The piston rod caps and crossheads are of hammered scrap iron, turned and polished. The eccentrics are of cast iron, held on the shaft by keys of steel or scrap iron. The eccentric rods are of hammered scrap iron. The slides are of approved design, accurately planed and scraped on the sliding surfaces. The bottom slides are flanged or dished to prevent any waste of oil. The connecting rods are of hammered scrap iron, forged in one length without weld. They are fitted with all necessary brass steps, gibs, cotters, and safety screws. The rods are machined and polished all over. The crank shaft is of hammered scrap iron; the journals for the same are of ample dimensions. The pedestals or plummer blocks have heavy steps of the best selected brass. The foundation plates are of cast iron and of approved design. They are strengthened throughout by cross bars and ribs, and well bossed at the holding-down bolts. The fly-wheel is of cast iron, and accurately bored at the centre, where it fits on the crank shaft. A suitable steam stop valve is pro-

vided, together with the screwed ends and nuts of the holding-down bolts. The steam pipes are supplied, connecting the two steam cylinders. The engines throughout are of the best quality and workmanship.

Mr. D. K. Clark, in his excellent *Manual for Engineers*, which should have a place in every engineer's library, gives some useful information about compressed air. Experiments on the resistance of air through long pipes show that the diminution of pressure is very nearly directly as the length and as the square of the velocity, and inversely as the diameter, and the resistance is not varied by the density. A table of the loss of pressure in pipes for a length of 1,000 mètres (or 3,280 feet) and for diameters 10 to 35 centimètres (4 to 14 inches), at velocities of from 1 to 6 mètres per second (3·28 feet to 19·68 feet) has been prepared by a French engineer, M. Cornut, and is here given :—

LOSS OF PRESSURE BY FLOW OF AIR IN PIPES.
LENGTH OF PIPE, 3280 FEET.

Velocity at the entrance to the Pipe.	DIAMETER OF PIPE IN INCHES.					
	4	6	8	10	12	14
	LOSS OF PRESSURE IN POUNDS PER SQUARE INCH.					
Feet per Second.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
3·28	·114	·076	·057	·057	·038	·038
6·56	·500	·343	·250	·210	·172	·153
9·84	1·183	·800	·592	·477	·394	·343
13·12	2·060	1·374	1·030	·840	·687	·600
16·40	3·200	2·160	1·610	1·290	1·100	·923
19·68	4·446	2·964	2·223	1·778	1·482	1·280

At the works for excavating the Mont Cenis Tunnel the supply of compressed air was conveyed in a cast-iron pipe 7⅝ in. diameter. The loss of pressure and leakage of air from the supply pipes, in a length of 1 mile 15 yards, was only 3½ per cent. of the head. The absolute initial pressure was 5·70 atmospheres, and it was reduced to 5·50 atmospheres, whilst there was an expenditure at the rate of 64 cubic feet of compressed air per minute. In the middle of the tunnel, through a length of pipe of, say,

20,000 feet, or 3·80 miles, the absolute pressure only fell from 6 atmospheres to 5·7 atmospheres, or to 95 per cent. of the original pressure.

In dealing with the efficiency of compressed air engines Mr. Clark says the work by expansion would be an exact duplicate, in reverse, of the work expended for compression, and the two works would be equal to each other if the reverse actions took place between the same temperatures, pressures, and volumes. The efficiency of the combined compressor and motor would be equal to 100 per cent., irrespective of losses by friction and clearance. But, under practical conditions, the initial temperature for expansion is not more than that of the surrounding atmosphere; and in working by expansion back to atmospheric pressure, even between the same extremes of pressure, the volumes are smaller, since the temperatures are lower, and the efficiency must, of course, be less than 100 per cent.

In compressing dry air at 62 degs., Fahr., to two atmospheres of pressure in a non-conducting vessel, the temperature is raised to 178 deg., and the fall in reverting to 62 deg. is 178 – 62 = 116 deg. The loss of efficiency is in the proportion of 116 deg. to (461 + 178 =) 639 deg., the maximum absolute temperature; thus,

$$461 + 178 = 639 \text{ deg.}$$
$$461 + 62 = 523 \text{ deg.}$$

Difference or loss, 116 deg., = 18 per cent. of the maximum absolute temperature. Leaving 523 = 82 per cent. of the maximum absolute temperature.

For ratios of pressures or atmospheres—

2	3	4	5	10

the final temperatures for compression are

178 deg.	258 deg.	321 deg.	373 deg.	559 deg.,

and the reduced efficiency, supposing the initial temperature for expansion becomes 62 deg. Fahr., is

82	73	67	63	51 per cent.,

whilst the loss of efficiency is

18	27	33	37	49 per cent.

It is obvious therefore, that the lower the degree of compression applied to the air the less is the rise of tem-

perature, the less is the loss of heat by dissipation, and the greater is the efficiency of the machine. When an initial temperature can be maintained for the expansion engine higher than that of the surrounding atmosphere, the range of temperature within which the air may be expanded before it arrives at the freezing point, as a lower limit, is greater than if it commence at atmospheric temperature, and the performance is also greater in the same proportion. When the compression is carried to ten atmospheres the efficiency for expansive working just indicated is only 51 per cent. Add that the efficiencies of the machines themselves—namely, the compressor and the power engine—are factors for the calculation of their resultant efficiency; and if the efficiency of each machine be taken at 80 per cent., the combined percentage of the two machines is $\frac{80 \times 80}{100}$, = 64 per cent., or two-thirds; and 64 per cent. of 51 per cent. is 33 per cent., the resultant efficiency of the compressor and engine working to ten atmospheres. Similarly it is found that the resultant efficiency, working to two atmospheres, is 52 per cent. The less the degree of compression the greater is the efficiency, because the loss is the proportional loss from the intermediate reduction of temperature. In general practice the resultant efficiency rarely exceeds 30 per cent.

Mr. Pickard illustrates the difference of the conditions and the efficiency of the work of compressed air in three cases, for which he adopts the initial temperature 32 deg. Fahr. He supposes that in the first and second cases the pressure and temperature are raised adiabatically during compression—that is, the temperature increases with the pressure—and that the temperature relapses to the normal point, 32 deg. Fahr., before the air is applied to work; and that in the third case the temperature is constant at 32 deg. Fahr., whilst the air undergoes compression.

1st Case: Air compressed, cooled, and expanded within the same cylinder, without any reservoir. 2nd Case: Compressed air cooled in a reservoir. 3rd Case: Air cooled during compression. The pressure to which the

air is compressed is in each case six atmospheres, whilst the final volumes to which it is compressed, taking the initial volume as 1, are—

Final Volume.	Fraction of Initial Volume.	During the Interval.
1st Case—0·281, or	1/3·5	Pressure falls to 3·56 atmospheres.
2nd Case—0·281, or	1/3·5	Final volume reduced to $\frac{1}{6}$ initial.
3rd Case—0·167, or	1/6	Pressure and volume stationary.

The final pressures, volumes, and temperatures are subjoined, and to these are added the efficiency for each case, or the ratio of the useful work done to the work expended in producing the supply of compressed air:—

	Final Pressures. Atmospheres.	Final Volume. Total = 1.	Final Temperature. Initial = 32 deg. F.	Efficiency. Compression = 1.
1st Case	1	·69	—119 deg.	36·4 per cent.
2nd Case	1	·595	—168 deg.	59·2 „
3rd Case	1	·595	—168 deg.	78·0 „

Ordinary practical conditions oscillate between cases 2 and 3, and it is clear that the more the air is cooled during the process of compression the less is the expenditure of work on compression, and the greater is the resultant efficiency. Mr. Pickard gives the following for the respective efficiencies for various pressures in the third case, and in the case when the air is admitted, for the whole of the stroke, without expansion.

Pressures in Atmospheres.	Efficiency in the Third Case per cent.	Efficiency without Expansion per cent.
1	100	100
2	90·6	72·1
4	82·4	54·1
6	78·0	46·0
8	75·2	42·1
10	72·9	39·1

It may be inferred that under every condition the efficiency is reduced as the pressure is multiplied. The rise of temperature during compression is much less when moisture is present in the air than when the air is dry. Atmospheric air at 68 deg. Fahr. initial temperature, when compressed to seven and a-half atmospheres, rises, if dry, to 490 degs. Fahr., and if sufficiently moist, to 194 degs. Fahr. only. The work is the same for dry air and moist air at 68 degs. Fahr. when compressed to one and a-half atmospheres. For a less degree of compression it is rather less for dry air, but for higher compressions it is less for moist air. For 7½ atmospheres it is 14 per cent. less.

When moisture is present in air in the condition of saturation the fall of temperature during expansion is greatly less than would take place when dry air is expanded. That a compressed air engine may work without the freezing of any moisture or vapour in the air, it should not exhaust at a temperature less than the freezing point. The following table gives a few examples of the maximum ratio of expansion that may be practised, with given initial temperatures, when the final temperature is to be 32 deg. Fahr.:—

Temperatures.		Ratio of Expansion.	
Final.	Initial.	Dry Air.	Air with Sufficient Moisture.
32 Fahr.	40	1·05	1·10
32	50	1·13	1·24
32	60	1·22	1·38
32	62	1·23	1·41
32	68	1·28	1·50
32	70	1·30	1·56
32	80	1·37	1·75
32	90	1·47	2·00
32	100	1·57	2·28
32	110	1·67	2·63
32	120	1·76	3·00
32	130	1·88	3·45
32	140	2·00	4·00

This table shows that air at 120 degs. Fahr. may be introduced into the cylinder at a pressure of three atmospheres and expanded to atmospheric pressure without risk of interference from the freezing of moisture, while

with dry air the maximum pressure under the same condition is only 1·76 atmospheres.

It has not been possible within the compass of this chapter to deal with nearly all the very numerous types of air-compressing engines brought into operation during the last two generations; it is matter for regret that valuable information and sketches from Mr. W. E. Garforth, of Normanton, and Mr. E. H. Birley, of Barnsley, came to hand too late to be used here; but commencing with 1850, and ending with the present time, sufficient examples have been taken of home and foreign machinery to give the reader some general and comprehensive knowledge as to what has been done. The opinions of the highest authorities have been given, and the results of consideration, calculation, and experiment in our own land and abroad.

CONCLUSION.

Now comes the end of the second volume of the *Mechanical Engineering of Collieries*, and although some subjects forming a part of the original intention four years ago have not been included, such as coal-cutting, tunnelling, boring machines, safety cages, and detaching appliances—material, as some friends and many acquaintances have suggested, for a third volume—even now this loss may have been counterbalanced to some extent by other subjects, not intended, having been included, and all the sections with more than the proposed fulness. The labour has been considerable, and the results are not striking. But it is hoped a text-book

on colliery engineering has been provided, written so that anyone at all conversant with the subject can understand it; and possibly some engaged in mining operations may be assisted in their arduous work, and mining students find their pathway to distinction made a little clearer by the facts placed at their disposal in these pages. That has been, and is the writer's highest ambition, and perhaps, after all, it is the noblest and most useful which a writer could have.

THE END.

INDEX.

Abram Collieries, 1
Accumulator for pumps, 168
Adams, Brown and, 24
Adamson, Daniel, 304
Air compressing machinery, 321
" " Bramwell on, 334
Air compressing machinery, D. K. Clark on, 344
Air compressing machinery, Cochrane on, 333
Air compressing machinery, Cowper on, 324, 333
" " Daniel on, 331
" " Firth on, 332
" " Geach on, 335
Air compressing machinery, Pickard on, 346
Air compressing machinery, Siemens on, 324
Air compressing machinery, speed of, 331
Air compressing machinery, Sturgeon's, 339
Air compressing machinery, Walker's, 341
" " Wendelstein on, 337
Air for ventilation, weight of, 3
Air, loss of power by flow of, 344
Air pump, 87.
" of pumping engine, 112
" links, 111
Air vessels, 170
Air, work in, 204
Albert, Prince Consort, 59
Aldwarke Main Collieries, 291
Alexandra Colliery, 28
Alexandria, Hero of, 59
American system of cooling castings, 143
Amsterdam Exhibition, 163
Angle pedestal of hauling engine, 282
Angle pulley and frame, 318
Annealing steel castings, 312
Apparatus for detaching tubs, 237, 249
Appliances in case a chain breaks, 264
" " rope breaks, 228
Ardennes, slate mines of, 209
Armour plates, 309
Astley and Tyldesley Collieries, 24, 107
Attachment of tubs to endless chain 257
" " endless rope, 284
Atmospheric pumping engine, 75,
Attercliffe and the steel industry, 319
Automatic expansion for winding engines, 20

Bailey's fan-recorder, 38
Bainbridge, Emerson, 210, 284
Balance box of pumping engine, 113
Bands and belts, travelling, 6
Banging pieces on pump rods, 121
Barometer of Torricelli, 72
Beam centre of pumping engine, 110
Beams of timber, built up, 116
Bearings, 300
Beighton's engine, 78
Bennett Woodcroft, 59
Berkeley and haulage, 234
Bickershaw Collieries, 1
Blakey's engine, 78
Blow-through valve, 149
Boilers, horse-power of, 201
" weight of, 201
" underground, 52
" the Cornish, 95
" number required, 201
" plates of, 200
Boot-leg for pumps, 124
Boring at Whitehaven, 176
Boxes, self-oiling roller, 318
Bramwell and the injector, 12
" " air-compressing machinery, 334
Branches in endless chain haulage, 253, 256
" " rope haulage, 276
" tail-rope haulage, 248
Brass, weight of, 200
Breakage of ropes, 230
Briart, M., 39
Bridge Pit haulage, 272
Bridge rails for haulage, 209
Bridle chains in haulage, 229
Brinsop Hall Collieries, 267
Britannica, Encyclopædia, 208
Brooks and Pickup, 38
Bronze, the age of, 309

Brown and Adams, 24
Brown and Co., John, 292
Bucket lifts, 124
Bull engine, 103
Burn's brake, 4, 219
Burnley Collieries, 165, 251
Butterfly clacks, 122

Calcutta Exhibition, 310
California Colliery, 279
Callon and the Paris School of Mines, 211
Car House Collieries, 291
Casting pipes, vertically and horizontally, 142
Cast iron, weight of, 201
Cataract in pumping engines, 38
Catch box gearing in Burnley haulage, 253
Causes of low useful effect in compressed air, 324
Caux, Salomon de, 63
Centigrade thermometer, 197
Chains and cappings, 228
" ropes, safe load, 230
Chain haulage, endless, 250
Chesterfield and Derbyshire Institute of Engineers, 285
Cinder Hill Collieries, 271
Circumferential velocity of fan, 205
Clacks for pumps, 122
Clay Cross pumping engine, 96
Clifton Collieries, Nottingham, 39, 267
Clifton Hall Collieries, Lancashire, 262
Clip hook in endless rope haulage, 287
Clip pulleys, 163
Clutch gear in haulage, 247
Coal cutting machines, 331
Coal, efficiency of, 185
Coal per h.p. per hour in engines, 83
Coals, the cleaning of, 5
Cochrane, W., 210
Cockson's ventilating fan, 28
Co-efficient of friction, 216
Cold water cistern of pumping engine, 112
Collapsing strength of boilers, 201
Colliery proprietors and inventors, 330
Coltness haulage by endless chain, 262
Columns of pumping engine, 110
Commission on safety lamps, 292
Compound differential pumping engine, 128
Compound hauling engines, 293
Compounding, 302
Compressed air machinery, 321
Compressed air machinery, Bramwell on, 334
Compressed air machinery, D. K. Clark on, 344
Compressed air machinery, Cochrane on, 333
Compressed air machinery, Cowper on, 324, 333
Compressed air machinery, Daniel on 331
" " Firth on, 332
" " Geach on, 335
Compressed air machinery, most effective pressure, 322
Compressed air machinery, Pickard on, 346
Compressed air machinery, speed of engines, 331
Compressed air machinery, Siemens on, 324
Compressed air machinery, Sturgeon's engines, 339
Compressed air machinery, useful effect, 322
Compressed air machinery, Walker's engines, 341
Compressed air machinery, Wendelstein on, 337
Condensation by injection, 75
Condensation, water for, 99
" in pipes, 144
Condenser, the separate, 83
Condenser of pumping engines, 112, 161
Condensers for pumps 147.
Condensing and expansive engines, 93
" non-expansive engines, 93
Condensing water, 190
Conductivity of metals, 192
Connecting rod and crank, 83
Connecting rods of hauling engine, 279, 299
" " air compressors, 343
Connection box of pumping engine, 112
Contraction of steel castings, 312
Copper, the effects of heat on, 200
Cornish bull engine, 103
" compound condensing engine, 160
Cornish engine and fly wheel compared, 102
Cornish pumping engine, 95
Cornish pumping engine, Watt and the, 47
" steam pump, 155
" valves, 122
Corliss winding engines, 3
Curves and rollers, 208
Cossall Colliery, 275
Cost of railway conveyance, 210
Coupe's machinery, 4
Covers of cylinders, 161
C pulleys for hauling, 282
Crank and connecting rod, 83
Cross head of pumping engines, 110
Cugnot and the locomotive, 82
Curves, endless chain on, 259
Cylinder cover and gland, 83

Cranks of hauling engines, 280, 299
Crank shaft of air compressors, 343
„ „ hauling engines, 280
Cross heads of air compressors, 343
„ „ hauling engines, 279, 299
Cylinder of pumping engine, 110
Cylinders of air compressors, 343
„ „ hauling engines, 278, 298

Daglish and haulage, 210
Daglish's machinery, 4
Daniel and air-compressors, 331
Davey, and pumping appliances, 128
Davies, Hamer and Metcalfe's exhaust injector, 15
Dead plate by James Watt, 83
Dean, Forest of, 209
Delivery of water, 199
Derbyshire Institute of Engineers, 285
Detaching apparatus, 237, 249
Diagram of energy, by Watt, 92
Diamond rock-boring machine, 330
Differential pumping engine, compound, 128
Dip workings, pumping water from, 166
Disc valves for pumps, india-rubber, 122
Double-beat valves, 122
Drawbars of tubs, 228
Driving pulley for endless chain, 254
„ wheels for haulage, 286
Drums for haulage, 221
„ for hauling engines, 299
„ for winding, compensating, 202
„ loose on shaft, 247
Duty of an engine, 183
Dynamometer experiments, 263

Eccentrics and hoops, 281, 299, 343
Effect of compressed air, useful, 323
Elasticity, moduli of, 196
Electricity as a motive power, 212
Elizabeth Pit, Whitehaven, 176
Ellis Lever and safety lamps, 292
Encyclopædia Britannica on mining, 208
Endless chain haulage, 250
„ „ at Burnley, 251
„ „ Clifton Hall, 262
„ „ Coltness, 262
„ „ Gannow, 261
„ „ Hapton Valley, 260
„ „ Rowley, 261
„ „ South Wales, 262
„ „ attachment, 257
„ „ experiments with dynamometer, 263
„ „ on curves, 259
Endless chain, safety appliances, 264
„ „ speed of, 258
Endless rope haulage, 266
„ „ at Bridge Pit, 272
„ „ Brinsop Hall, 275
„ „ California Pit, 270
„ „ Cinder Hill, 271
„ „ Clifton, 285
„ „ Mesnes Colliery, 273
„ „ Newsham, 271
„ „ Scot Lane Collieries, 273
„ „ Shire Oaks, 269
„ „ attachment, 269, 271 273, 284, 287
„ „ in Lancashire, 267
„ „ „ Midlands, 267
„ „ on curves, 272, 288
„ „ speed of, 270, 271, 272, 284, 288
„ „ working pumps, 163
Energy, Watt's diagram of, 92
Engineers, D. K. Clark's manual for 344
Engines for direct haulage, 219
„ pumping, 47
Evans and Sons, Wolverhampton, 154
Examinations in mining, 139, 208
Examples of haulage, 221
„ pumping, 150
Exhaust steam injector, 10
„ „ „ experiments with, 17
„ „ „ theory of, 17
Exhaust steam underground, 146
Exhibition at Amsterdam, 163
Expansion gear for winding engines, 20
„ in Cornish pumping engines, 105
„ Is it gain? 297
„ joints, 145
„ of steam, 91
„ produced by heat, 195
Experiments with dynamometer, 263
Eyre's patent forged steel wheels, 292

Fahrenheit's thermometer, 194
Falling bodies, 200
Fan as improved by Cockson, 28
Fan, circumferential velocity of, 205
Fan driven with rope gearing, 31
Fastening steel wheels upon axles, 313
"Favorite" steam pump, 173
Feet on endless chain pulley, 255
Fire engine by Hero, of Alexandria, 60
Firth on air compressing, 332
Fisher's hauling gear at Clifton, 285
Floor-plates of pumping engine, 113

Thread-cutting machine, 1
Three-throw engine, 1
Three-throw pump, 1
Throttle-valve, 1
Thrust-block, 1
Thrust-bearing, 1
Tidal harbour, 1
Tidal wave, 1
Timber, 1
Tin, 1
Tinning, 1
Tipping-bucket, 1
Tobin tube, 1
Tonnage, 1
Tool-grinding machine, 1
Tool-holder, 1
Tool-post, 1
Tool-rest, 1
Tool-steel, 1
Toothed gearing, 1
Torpedo, 1
Torsion, 1
Tower, 1
Trade-mark, 1
Trade-unions, 1
Trafalgar, battle of, 1
Trafalgar Square, 1
Trafalgar Square fountains, 1
Trafalgar, battle of, 1
Trafalgar, battle of, 1
Trafalgar, battle of

Hints for steel-users, 320
Holding, W., Brinsop haulage and, 275
Holding-down bolts of pumping engine, 112
Holman's condenser, 147
Horizontal fly-wheel pumping engine, 143
Horse-power of engines, 185
„ boilers, 201
Horse-trees for pumps, 115
Hot-water cistern of pumping engine, 112
Howe, W., and Clay Cross, 97
Hund, German, 209
Huntingdon's tests, 312
Huntsman and the steel industry, 319
Hydraulic cylinders of cast steel, 312
Hydraulic method of forcing wheels on axles, 317
„ pumping engine, 162

India-rubber disc valves for pumps, 122
Indicating air-compressing engines, 332
Indicator at collieries, 33
„ for cylinders by Watt, 83
Inertia of water, 55
Injection apparatus of pumping engine, 112
„ condensation by, 75
Injector, Bramwell on the, 12
„ experiments with exhaust steam, 17
„ Giffard and the, 10
„ Goodeve on the, 13
„ Robinson on the, 10, 12
„ Siemens on the, 12
„ the exhaust steam, 10
„ theory of, 13
„ theory of exhaust steam, 17
Institute, the North of England, 210
Interchangeability of steel castings, 317
Intercolonial Coal Mining Co., Montreal, 298
Inventions of Watt, 83
Inventors and colliery proprietors, 331
Iron lagging for drums, 221
Iron tubs, 257

Jacket, the steam, 83, 90
Jackets of air compressing cylinders, 343
Jig wheels and drums, 218
Joints, expansion, 145
Joints of pump stocks, 120
Joy's valve gear, 301

Kennedy's tests, 312
Kirkaldy's tests, 312
Kirkless Hall Co., California Pit, 270

Lamb and Moore's pumping, 148
Lambton Colliery pumping arrangements, 132
Lamps, safety, 292
Lancashire endless rope haulage, 26
„ steam boilers, 95
Landless and mechanical screening, 41
Latent heat, Black's theory, 85
Lead, weight of, 200
Lead and lap of valves, 280
Lean's Reporter on Cornish pumping, 104
Leathers of pump buckets, 162
Leech, A. H., and Brinsop Haulage 275
Leupold's steam engine, 77
Lever, Ellis, and safety lamps, 292
Lewis, H., and Linby and Annesley Collieries, 288, 342
Lewis and Wipperman's air vesse appliance, 170
Lift, bucket, 124
„ plunger, 114
„ running, 124
Linby Collieries, 288, 342
Lindsay Wood, 210
Link motion, its defects, 301
Lishman and Young's underground locomotives, 323
L leg pumping arrangement, 125
Longmere, J. B., and mining at Whitehaven, 175
Loss of pressure by flow of air, 344
Lowther, Lord, and mining at Whitehaven, 175
Low useful effect of compressed air, 323

Machinery for compressing air, 321
Madrid Exhibition and Hadfield's steel, 310
Main beam of pumping engine, 110
Manganese steel, Hadfield's, 318
Manual for Engineers, D. K. Clark's, 344
Manual labour in haulage, 212
Mariemont Collieries, Belgium, 39
Marley Hill colliery haulage, 234
Materials, strength of, 190
Matthews, R. F., and haulage, 210
Mechanical screening, 38
Mechanical ventilation, 204
Melbourne Exhibition and Hadfield's steel, 310
Memoranda for mining engineers, 184
Mesnes Colliery haulage, 273
Metals, conductivity of, 192
Metcalfe, Hamer and Davies' exhaust injector, 15
Mine engineering, Greenwell on, 207

Midland system of endless rope haulage, 267
Miners' friend, of Savery, 69
Mines of Ardennes, slate, 209
Mines, Paris School of, 211
Mining and Mechanical School, Wigan, 5
Mining, *Encyclopædia Britannica* on, 208
Mining examinations, 139
Mining machinery at Whitehaven, 170
Mitre valves, 122
Molten cast iron, temperature of, 312
" " steel " " 312
Mont Cenis Tunnel air compressors, 344
Motion bars, 299
Murdock and the steam engine, 84
Murton Colliery Haulage, 244

Newcomen's atmospheric engine, 73
Newsham Colliery haulage, 271
Nicholas Wood, 241
Non-condensing and non-expansive engines, 93
Non-condensing and expansive engines, 93
Norley Colliery pumping arrangements, 147
North Hetton Collieries, 241
North of England Institute of Engineers, 210
Nottingham coalfield, 285

Ormerod's safety links, 4
Over the tubs, endless rope, 267, 265

Papin and the steam engine, 67
Parallel motion of Watt, 83
Paris exhibition and Hadfield's steel, 310
" School of Mines, 211
Peace, G. H., and Astley and Tyldesley Collieries, 25, 107
Peasley Cross Colliery pumping engines, 103
Pedestals of pumping engine, 111
" " hauling engine, 280
Penrice tunnelling machine, 330
Pepper Mill Brass Foundry Co., 36
Pickard on compressed air, 346
Pipes, concentric and eccentric, 143
" in shafts, 145
" table of strengths, 118
Piston pumps, 157
Pit banks at Abram Colliery, 4
Pit work for pumps, 114
Planet wheels, sun and, 83
Plank roads for haulage, 207
Plunger lift, 114
Pneumatics of Hero of Alexandria, 59
Piston, and rod of air compressors, 343
" " " hauling engine, 279
" " " pumping engine 110, 161
" speed, 295
Pontypridd, Great Western Colliery at, 24
Porta and the steam engine, 63
Power for haulage, 213
Pressure by flow of air, loss of, 344
Pressure gauge, 83
Proportioning cylinders of pumping engines, 305
Pulley and frame, Hadfield's steel, 318
Pulleys, clip, 163
" for endless chain haulage, 254
" friction of headgear, 216
Pump buckets, 125
" clacks, 122
" condensers, 147
" leathers, 162
" rods, 120
" seating, 115
" stocks, 117
" " form of, 119
" " joints of, 120
Pumps, balancing arrangements for, 127
" boot legs for, 124
" distance placed above water, 53
" lodge room for, 115
" mishaps with, 126
" strength of horse-trees for, 115
Pumping engines and appliances, 47 to 173
" " Astley and Tyldesley, 107
" " Clay Cross, 96
" " Davey's compound, 128
" " Evans and Sons, 154
" " examples and rules, 150
" " L leg arrangement, 125
" " Peasley Cross, 103
" " specifications of, 110, 161
" " speed of, 150
" " the Cornish, 95
" " underground, 140 to 164
Pyramid valves, 123

Railway conveyance, cost of, 210
Rainford Colliery haulage, 283

Ram steam pump, 156, 158
Receivers for compressed air, 341
" " steam, 239
Recesses in pumping pit shafts, 116
Recorder, Bailey's fan, 38
Resistance to compression, 191
" twisting, 191
Reversing shaft, 281
Rhodes, C. E., and Car House Collieries, 291
Riddles for screening coals, 6
Rivington on strength of materials, 191
Robinson and the injector, 10, 12
Rock-boring machines, diamond, 330
Roller boxes, self-oiling, 318
Rolleys and corves in haulage, 208
Rope gearing for fans, 31
Ropes and chains, safe load, 230
Ropes on steel castings, 316
Rotary valves for pumps, 156
Rowley Colliery haulage, 251, 261
Royal Commission and safety lamps, 292
Rules as to power of Cornish engine, 106
" " pumping engines, 151
" " Winding drum and steam pressure, 188
Running lifts, 124
Russell, R., and Coltness haulage, 262

Safe load for chains, 230
Safety appliances for endless chains, 264
" " in haulage, 228
Safety lamps, 292
Salt Mines, pumping engines for, 167
Savery and the "Miners' Friend," 68
Saville and the exhaust injector, 15
Saving to ropes by steel castings, 316
Scalegill Colliery, Whitehaven, 176
Scarborough, G. E., and pumping, 148
Science and Art Department, 138,208
Scotland, air compressors in, 326
Scot Lane Colliery haulage, 273
Screens, experiments with, 41
" mechanical, 38
Seaham Colliery haulage, 242
Seaton Delaval Colliery haulage, 243
Seating of pumps, 115
Self-acting gradients, 218
Self-contained hauling engine, 284
Self-oiling roller boxes, 318
Severn tunnel railway, 335
Shafts, pipes in, 145
" endless chain in, 252
Shire Oaks Colliery haulage, 269
Side pulleys, 226
Siemens on air compressing, 324
" Joy's valve gear, 301
" the injector, 12
Signal indicators for collieries, 33
Single-acting engines, 89
Single beat valves, 122
Siphon, the, 54
Sledge or Sled, 207
Slide bars and blocks, 110, 279, 343
Sliding piece and windbore of pump, 124
Smeaton and pumping engines, 79
Snifting valves of engines, 76
South Wales endless chain haulage, 262
Specification of air compressors, 343
" compound hauling engine, 298
" Cornish engine, 110
" Cornish steam pump 161
" hauling engine, 278
Specific heat, 194
Speed of air compressors, 331
" Cornish engines, 106
" endless chains, 258
" endless ropes, 288
" pumping engine, 150
Staveley Colliery pumping engines, 138
Steam, double acting, 83
" different kinds of, 189
" heat, pressure, and volume of, 100
" injector, the exhaust, 10
" lifts at Abram Colliery, 4
" pumps, 141
Steel castings, annealing, 312
" " contraction of, 312
" castings, Hadfield's, 308
" cylinders, hydraulic, 312
" Foundry Co., Hadfield's, 310.
" users, hints for, 320
" wheels, patent fastening, 313
" " self-oiling, 315
St. Gothard tunnel air compressors, 337
Stephenson and Watt, 81
Steven's expansion gear for winding engines, 22
Stewart and the injector, 10
Strength of pipes, table of, 118
" materials, 190
Stop valve of pumping engine, 112
Stuffing boxes and glands, 161
Sturgeon high speed air compressors, 339
Tail rope Committee, 210, 234
" haulage, 233
" " at Harraden, 244
" " at Hetton, 241
" " at Marley Hill, 234
" " at Murton, 244
" " at Seaham, 242
" " at Seaton Delaval, 243

Tail rope haulage, Greenwell on, 234
Tandem engines, 161
Tangye's pumps, 147
Tanks for winding water, 49
T headed and bridge rails, 209
Thermometers, 197
Three-cylinder engines, 304
Temperature of fusion, 193
Tenacities, 190
Throttle valve, 83
Tightening frames of hauling arrangements, 276
Tonkin's patent pump condenser, 161
Torricelli and atmospheric pressure, 71
Tram plates of cast iron, 209
Transverse strengths, 191
Treble ram pumps, 172*
Tubs, friction of, 218
Tubs of iron, 257
Tunnelling machine, Penrice's, 330
Turbines working haulage, 212
Twisting strengths, 191

Underground pumping engines, 140
„ „ „ speed of, 130
Underground pumping engines, rules and examples, 151
Underground pumping engine, Evans's, 154.
Underground exhaust steam, 146
„ locomotives, 323
„ piston pumps, 157
„ roads, 215
Under the rails, endless rope, 285, 267
Useful effect of compressed air, 323
Users of steel, hints for, 320

Vacuum, Galileo and, 71
„ theory of, 70
„ Torricelli and, 71
Valves, blow through, 149
„ Cornish, 122
„ double beat, 122
„ india rubber disc, 122
„ mitre, 122
„ of air compressing engines, 326, 328, 331, 341
„ of gun metal, 162
„ pyramid, 123
„ rotary disc, 156
„ single beat, 122
„ steam, exhaust, and equilibrium, 89
„ stop, 112
„ throttle, 83
Valve boxes of pumping engines, 111
„ chests, 161
„ gear, differential, 129
„ „ Joy's, 301
„ motion of hauling engine, 280
„ spindles, 280

Velocity of fan, circumferential, 205
„ head, and quantity of water, 198
Ventilating fan, Cockson's, 28
Ventilation, mechanical, 204
Vertical and horizontal hauling engines, 219
„ pumping engine, 160
„ pulleys, 225
Volume of steam, 100

Waddington and Burnley Collieries, 258
Wales, air compressors in, 328
„ South, endless chain, 262
Walker Brothers, Pagefield, Wigan 4, 298, 341
Warner's pumping engines, 172*
Watt, 81
„ and the Cornish pumping Engine, 47
Water columns, pressure of, 198
„ delivery of, 199
„ gauge, 205
„ jackets for air compressors, 343
„ tanks, 49
Waterworks, Cornish engines at, 105
Wear of hauling ropes, 224
Weight of pipes, 200
Wendelstein on air compressors, 337
Wheels, Eyre's patent forged steel, 292
„ fast and loose, 215
„ for blast furnaces, 318
„ secured by hydraulic power, 317
Whitehaven, mining machinery at, 174
Whitworth's compressed steel, 312
Wigan Mining and Mechanical School, 5
Wigan Coal and Iron Co., 28
Wilkinson's machinery, 4
William Pit, Whitehaven, 177
Winding by endless chain, 252
„ drum, rule as to size of, 188
„ engines, expansion gear for, 20
„ water, 48
Windbore, sliding piece and, 124
Wipperman and Lewis's air injector, 170
Wood and Co., engineers, Wigan, 275
Wood lagging for drums, 221
Wood, Nicholas, 241
Worcester, Marquis of, 63
Work in air, 204
Wright, G. H., and haulage, 234
Wrought iron, weight of, 201

Young and Lishman's underground locomotives, 323

WILKINS & CO.,

(Late WILKINS & WEATHERLY),

39, *Wapping*, *London*, *E.*,

WIRE ROPE MAKERS.

Weighing Machinery.

HODGSON AND STEAD,
Egerton Iron Works,
WINDSOR ST. REGENT ROAD,
SALFORD,
MANCHESTER.

"MEN MAY COME AND MEN MAY GO BUT I GO ON FOR EVER."

TWELVE YEARS' SUCCESS.

Important Improvement.

MORGAN'S

CELEBRATED IMPROVED SCALE-PREVENTING COMPOUND.

"USED AT HER MAJESTY'S ROYAL ARSENAL, WOOLWICH."

Many years' experience and scientific research have enabled W. H. MORGAN to overcome the chief difficulty hitherto known in preventing incrustations—viz., the production of an INVALUABLE combination of Chemicals at a LOW PRICE which CANNOT BE SURPASSED as a preventive of scale, and is not only guaranteed NON-INJURIOUS, but positively PRESERVES THE BOILER PLATES from the action of destructive acids.

Opinions of the Leading Scientific Journals,
And interesting PAMPHLET on the "Scientific Treatment of Water for Steam Boilers," sent Post Free to any address.

Samples of Feed Water for testing, with orders and enquiries, are sent from all parts.

W. H. MORGAN, Consulting and Chemical Engineer, Gloucester.

IMPROVED PORTABLE HOISTING ENGINES.

DOUBLE CYLINDER



TESTIMONIAL

From BOWMAN & Co., Muiredge, Cameron, and Rosie Collieries, Buckhaven, 1st October, 1884.

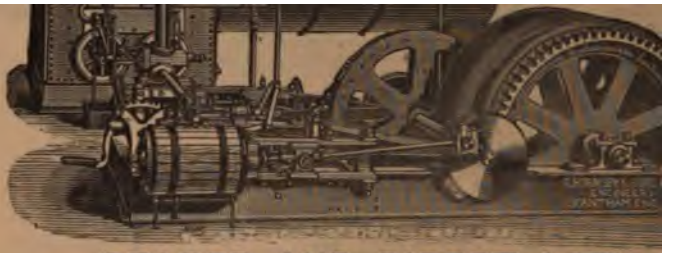
DEAR SIR,—I have much pleasure in certifying that your Hoisting Engine No. 7 on List, has been at use at our Works for 18 months, and during that time has given great satisfaction. It has done all the winding required during the sinking of one of our large shafts to the depth of 60 fathoms, the weight of kettle and spoil being about 13 cwt.

I am, yours truly,
ARCHD. BOWMAN, Manager.

W. M. MELVILLE,

ENGINEER AND IRONFOUNDER.

SINCLAIRTOWN FOUNDRY, KIRKCALDY.



GEARED AND DIRECT ACTIN

WINDING ENGI

Of 10, 16, 20, 25 and 30 HORSE POW

SINGLE OR DOUBLE WINDING D

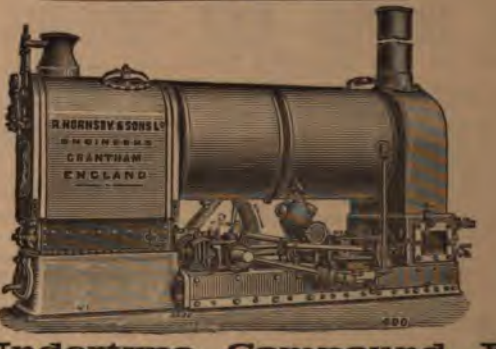
Driven by Gearing and Portable or Semi-Po

ENGINES, 4 to 25 H.P.

AND FITTED WITH

BRAKE, CLUTCH, OR PUMP CRA

AS REQUIRED.



Patent Undertype Compound E

SYDNEY F. WALKER & OLLIVER,

ELECTRICAL ENGINEERS & CONTRACTORS.

CONTRACTORS for the Erection and Maintenance of TELEGRAPHIC and TELEPHONIC Communications under all circumstances. IMPROVED

ELECTRIC SIGNALLING FOR COLLIERIES,

COALING SCREENS, BANKS, PIT BOTTOMS, AND MAIN ROADS LIGHTED WITH THE ELECTRIC LIGHT.

INSULATORS, SAL-AMMONIAC BATTERIES, WIRE SUPPLIED.

195, *SEVERN ROAD, CARDIFF.*
NEW BRIDGE STREET (HUNTER'S FORGE), NEWCASTLE-ON-TYNE.

HULME & LUND

MAKE A SPECIALITE OF

UNDERGROUND PUMPING ENGINES FOR MINE DRAINAGE,

HORIZONTAL AND VERTICAL DESIGNS.

Also PUMPING ENGINES, for working Hydraulic Machinery, Cranes Hoists, Presses, &c.

SINGLE, DOUBLE, AND QUADRUPLE-ACTING

"NOISELESS" STEAM PUMPS,

For Boiler Feeding and for all other purposes.

Many sizes in stock or progress.

Quotations for the above and other kinds of Engines sent free on application to

EGERTON STREET IRON WORKS,

CHESTER ROAD, MANCHESTER, S.W.

IMPROVED WINDING INDICATOR,

With Bell complete, to ring at any part of the draw.





INDICATING SIGNAL BELL,

For Collieries, Railways, Steamboats, Locomotives, Warehouses, Works, &c.

A Safe & Sure SIGNAL. Entirely SELF-ACTING.

SUPPLIED EITHER SEPARATE OR COMBINED,

Guaranteed BEST & CHEAPEST in the Market.

ELECTRIC BELLS & TELEPHONES a Speciality.

Prices, Testimonials, &c., to Patentee,—

C. PARKIN,

LIVERSEDGE, YORKSHIRE.

PRIZE MEDALS at Vienna, Nice, Arnheim, Brabant, Brussels, Mayence
Calcutta, Bury St. Edmunds, London, &c., &c.

JOHN WARNER & SONS,

Bell & Brass Founders
By Special

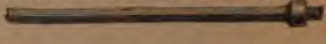
to Her Majesty,
Appointment.

HYDRAULIC AND SANITARY ENGINEERS, MILLWRIGHTS AND FOUNDERS, &c. &

THE CRESCENT FOUNDRY, CRIPPLEGATE, LONDON, E.C.; and
THE FOUNDRY WORKS, WALTON-ON-THE-NAZE, ESSEX.

Manufacturers of Wind Mills, Water Wheels, Steam Engines, Hydraulic Machinery
every description, Fire Engines, Hydraulic Rams, Deep Well Pumps, Centrifugal Pum
Horse Gear Frames, Engine Frames, &c., Cocks and Valves for Water at High or L
Pressure, Steam Engine and Boiler Fittings, &c., &c.

3 Gold 16 Silver, and 7 Bronze Medals Awarded, Calcutta Exhibition 1883-

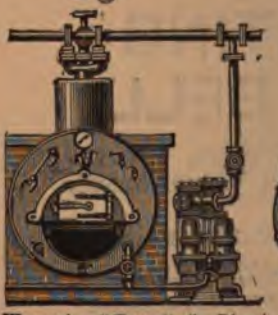


Warner's
BORING
TOOLS.
AND
MINING
MACHINERY

Illustrated
Catalogues
Post-free
upon
Application.

WARNER'S
PUMPING MACHINERY
For MANUAL, ANIMAL, STEAM, WIND & WATER POWERS

STEAM BOILERS, ENGINES and FITTINGS
For HAULING, HOISTING, WINDING, PUMPING, WIRE ROPE
TRANSMISSION, &c., &c.



Warner's "Favorite" Direct-Action Steam Boiler Feeders.
Silver Medal Awarded, Calcutta Exhibition, 1883-4.



Warner's Horizontal Direct-Action "Essex" Steam Pumps.
Silver Medal Awarded Calcutta Exhibition, 1883-4.



Warner's "Sa
Steam Ram Bo

WARNER'S PUMPING MACHINE
For every variety of Purpose and Applicatio

GEORGE CRADOCK & COMPANY,

WIRE ROPE WORKS, WAKEFIELD,

SOLE MANUFACTURERS OF

LANG'S PATENT ROPE,

Contractors to the Lords of the Admiralty,

Beg to call special attention to the application of Lang's Patent to the construction of

STEEL & IRON WIRE ROPES

For Collieries, Mines, Steam Ploughing, Aerial Railways, Capstans, Transmission of Power, &c.





LANG'S PATENT WIRE ROPE

WHEN NEW.



WHEN WORN.

ORDINARY OR OLD CONSTRUCTION

WHEN NEW.



WHEN WORN, SHEWING HOW THE WIRES BREAK ON THE CROWN OF THE STRAND.



A REWARD will be given for information of any Infringement of this Patent.



SYDNEY SMITH & SONS,
MANUFACTURERS,
BASFORD BRASS WORKS,
NOTTINGHAM

Smith's Patent Full-bore Cocks.
Smith's Patent Pressure Gauges.
Smith's Patent Whistles.
FUSIBLE PLUGS, INJECTORS,
Hydraulic Gauges, Gun-metal Steam Fittings of all kinds.
BRASS CASTINGS from 9d. per lb.
Illustrated priced Catalogue on application.
London: 37, Walbrook. Glasgow: 60, Howard-st.



THE "EXHAUST" INJECTO

(DAVIES, HAMER & METCALFE'S PATENT)

FEEDS BOILERS BY MEANS OF

EXHAUST STEAM ONLY.

Heating the feed-water up to 190° F.

Works on intermittent as well as constant running Engin

(See page 15 of this work.)

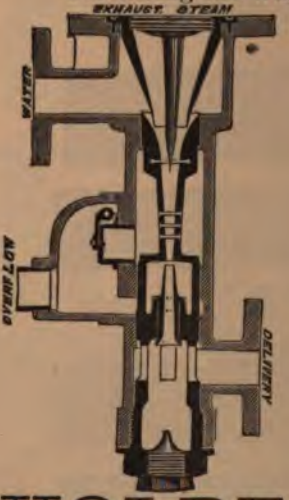
The Patent Exhaust Steam Injector Co. Limite

4, ST. ANN'S SQUARE, MANCHESTER.

PATENT "IMPROVED"
(RIGID NOZZLE)

EXHAUST STEAM INJECTO

For saving the Waste Steam from Non-condensing Engines.



THE IMPROVED FEATURES OF THESE INJECTORS ARE:

No Flap Nozzle or other internal lo pieces.

A stronger and simpler Injector of m reliable action.

Greatly increased efficiency of pres boiler power.

Substantial economy in Fuel, labour a maintenance over existing methods Boiler Feeding.

FOR PRICES & PARTICULARS APPLY

HOLDEN & BROOKE

ST. SIMON'S WORKS, SALFORD,
MANCHESTER.

Also Makers of the Patent "INFLUX" (live steam) Injecto

ALEXR. WILSON & CO., ENGINEERS,

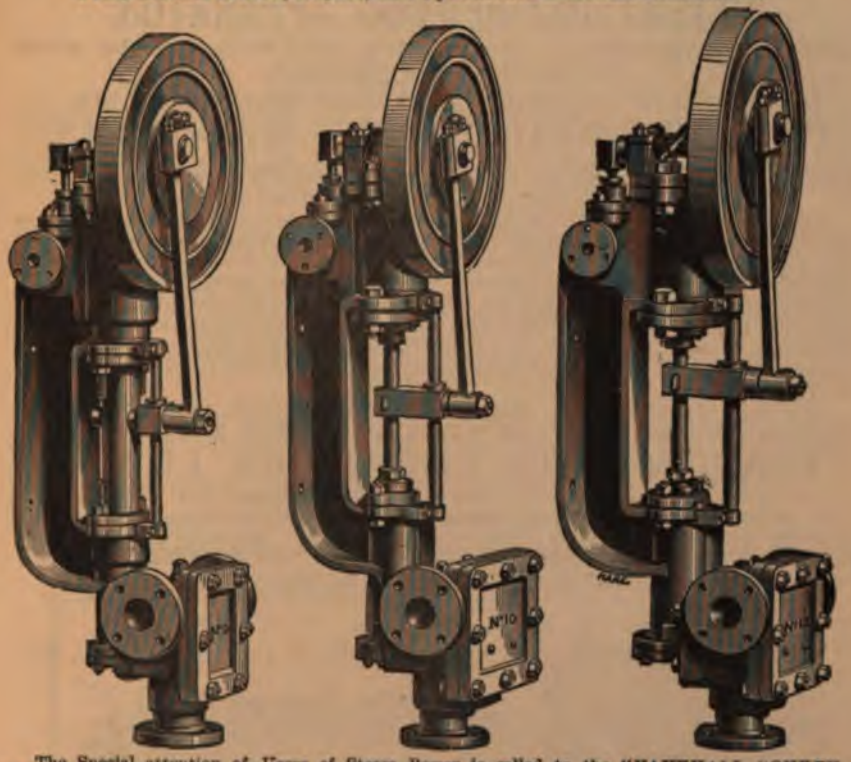
VAUXHALL IRON WORKS,

WANDSWORTH ROAD, LONDON, S.W.,

MANUFACTURERS OF

THE "VAUXHALL DONKEY PUMPS."

Prize Medals Havre, Naples, and Tynemouth Maritime Exhibitions.



The Special attention of Users of Steam Power is called to the "VAUXHALL DONKEY PUMPS," which are the only reliable Donkey Pumps in use. They are patronised by all the leading Shipbuilders and Engineers, and can be obtained from any Steamship Furnisher at home or abroad.

Over 9,000 of these Pumps are now in use on board Yachts and Steamships, in Breweries, Distilleries, Tanneries, Paper Mills, Cotton, Woollen and other Spinning Mills, Bleach Works, Dye Works, Chemical Works, Saw Mills, Collieries, Ironworks, Mines, and many other places where steam is used.

TABLE OF SIZES AND PRICES OF PUMPS.

No.	Diam. Ins.	Stroke. Ins.	Galls. thrown per hour.	Horse-power of Boiler supplied.	Price. £ s. d.
3	1	2	50	4	8 10 0
4	1½	2½	100	8	7 10 0
5	1½	3	150	12	10 0 0
6	1½	4	250	20	13 0 0
7	2½	4	400	30	15 0 0
*8	2½	4	700	50	17 10 0
9	2½	6	900	60	20 0 0
*10	2½	6	1500	100	22 10 0
*11	2½	6	1800	120	27 0 0
*12	3	6	2100	140	30 0 0
*13	3½	7½	2500	170	36 0 0
*14	2½	9	3000	200	45 0 0
*15	3	10	4000	300	55 0 0
*16	3½	12	7000	500	65 0 0

No. 3 (marked *) is designed specially for small Steam Launches, and has cylinder and pump cast in gun-metal. Nos. 4, 5, 6, 7, and 9 are single-acting, with gun-metal rams and glands. Nos. 8, 10, 11, 12, 13, 14, 15, and 16 are double-acting. Nos. 14, 15, and 16 have two water barrels. All clack valves are made in gun-metal for pumping hot water unless otherwise ordered. No extra charge for india-rubber valves and water plungers packed with leather cups.

A large Stock always on hand, from which Orders can be executed without delay.

ALSO MANUFACTURERS OF

The EXCELSIOR DIRECT-ACTING STEAM PUMPS for FEEDING BOILERS and other purposes.

BILGE and WATER BALLAST PUMPS, STEAM ACCUMULATOR and PROVING PUMPS, DEEP WELL and every description of PUMPING APPARATUS.

PATENT FUEL MACHINERY

FOR UTILISING SMALL COAL, COKE, &c., &c.

YEADON'S

IMPROVED GRINDING AND MIXING MACHINES.

COAL WASHING MACHINES. PATENT COAL DRYING MACHIN

PATENT DRY-HEATING APPARATUS.

Dispensing with Steam for Heating, and reducing the pi
required nearly one-half.

☛ THIS IS OF VITAL IMPORTANCE IN THE MANUFACTURE OF PATENT FUEL.

PATENT BRIQUETTE MACHINES

Adopted in England, Wales, France, Belgium, Spain, Sardinia, In
China, New Zealand, Nova Scotia, &c.

These Machines have recently been remodelled and improved throughout. T
are now fitted with Patent adjustable Feed motion and other improvements sugg
by several years' experience in the construction and erection of this class of machi
They are recommended by our Customers "as being the best machines they kno
after having carefully studied all the Briquette machines constructed at home
abroad." For Design, Workmanship and Economy in manufacture, our Patent
machinery as now constructed, is unequalled by any other made. Estimate
Complete Plants forwarded on receipt of particulars.—*Testimonials and full partic*
on application.

☛ N.B.—BEWARE OF INFERIOR IMITATIONS AS THE ABO
MACHINERY CAN ONLY BE SUPPLIED DIRECT FROM

YEADON & CO., ENGINEERS, LEEDS

CONTRACTORS FOR EVERY DESCRIPTION OF PLANT FOR

Collieries, Mines, Brickworks, &c.

Rigg's Patent Coal Tipping Machines & Curved Balanced Scre

(Described in the first Volume of this Work, Chap. XII. page 105.)



COLLIERY PLANT OF ALL DESCRIPTIONS,
Rigg's Patent Automatic Coal Drop and Floating Elevator for Bunkering Coal

For prices and particulars apply to

JAMES RIGG, Engineer

11, Queen Victoria Street, London, E.C.

Special First Award, Sydney, 1879. Silver Medal, Melbourne, 1880.
Gold Medal, Adelaide, 1881.

LLOYD AND LLOYD,

ALBION TUBE WORKS, BIRMINGHAM,

AND COOMBS WOOD TUBE WORKS, HALESOWEN,

MANUFACTURERS OF

WROUGHT-IRON WELDED TUBES & FITTINGS,

FOR GAS, STEAM AND WATER, &c.

BOILER TUBES IN IRON, HOMOGENEOUS METAL & STEEL,

Hydraulic Tubes, Boring, and Lining Tubes for Wells, &c.
Tuyere Coils.

LARGE TUBES UP TO 4-FT. DIAMETER.

London Office: No. 90, CANNON STREET, E.C.

Warehouses: LONDON, LIVERPOOL, MANCHESTER.

THREE PRIZE MEDALS,

PARIS EXHIBITION, 1878.

One Silver Medal for Improved Steel Music Wire;
One Bronze Medal for Steel Pinion and Round Wire;
ONE SILVER MEDAL (the ONLY PRIZE awarded) for

IMPROVED STEEL ROPE WIRE,

AWARDED TO

W. D. HOUGHTON

(ESTABLISHED 1820),

SANKEY WIRE MILLS, WARRINGTON.

WIRE *This Wire, by its extensive use, has become established as the very best in the market.*

Made from superior Cast Steel, and with careful and experienced supervision in every department of the manufacture, it is specially adapted for

COLLIERY, PLOUGH, TRAMWAY AND HAWSER PURPOSES

And every purpose where the Latest Improved Wire is necessary.

Pumps and Pumping Machin

JOSEPH EVANS & SONS, WOLVERHAMPTON.

SPECIALITIES.

On Pages 154 to 160.

WALKER BROTHERS,

ENGINEERS & BOILER MAKERS,

PAGEFIELD IRONWORKS, WIGAN.

WALKERS'

PATENT AIR-COMPRESSING ENGINES,

FOR COLLIERIES, STEELWORKS, CHEMICAL WORKS, etc., and as Supplied to

Her Majesty's Government for India.

Over 30,000 Indicated Horse-power of these ENGINES in operation.

WALKERS'

New Patent Improved "Guibal" Ventilating Fan

(Practically Silent at High Speeds, and without Vibration) with simple High Pressure or Compound and

CONDENSING ENGINES.

This Invention is applicable to any existing Fans, and enables them to be driven safely at a much higher velocity, and with almost perfect quietness.

WADDLE and SCHIELE FANS.

FISHER & WALKER'S

PATENT MACHINERY

For Underground and Surface Haulage, &c.

Now in operation in extensive Collieries, Iron Mines, etc.

By this Machinery the "Life" of the Rope is extended beyond all previous experience.

LOCOMOTIVES,

STEAM HAMMERS UP TO 15 TONS.

FORGE AND ROLLING MILL PLANT.

WINDING, PUMPING & HAULINC ENGINES.

BOILERS

HORIZONTAL and VERTICAL, STATIONARY and LOCOMOTIVE).

IRON AND STEEL FORGINGS up to 10 TONS.

HORIZONTAL AND VERTICAL ENGINES,

Condensing and Non-Condensing.

ROOFS, GIRDERS, BRIDGES, PIT CAGES, etc., etc.,

AND ALL KINDS OF

Iron and Steel Work.

BARRACLOUGH'S

PATENT NOISELESS CLIP PULLEY,

Used for Hauling, Pumping, or Driving Machinery, with Endless Wire Ropes.

Does not injure the Ropes. Will work in any position, and run either backwards or forwards.

For particulars apply to the Patentee and Sole Maker,

JOSEPH BARRACLOUGH, Engineer,

UNION FOUNDRY, BARNSLEY.



All kinds of SPUR, BEVEL, MITRE and MORTISE WHEELS.

Any Pattern Machinery, without patterns; any diameter and pitch.

Fly Engine. Improved Balance Slide Valves for Engines.

Patent METALLIC PISTONS, with Steel Coils.

Supplied in a few hours' notice; any sizes up to 30 in. diameter.

Agent for Parker & Weddle's Patent STEAM PUMPS, which are kept in stock, under them.

MORTAR MILLS, with Engine and Pulley combined.

Cylinders Bit-bored in their place by Special Machinery.

Maker of ALL KINDS of Colliery Castings, having a large Assortment of Patterns.

Maker of Colliery Winding Pumping and Hauling Engines, Air Compressors, &c.

WHEELDON'S

"XL" & "CROWN" LUBRICATING OILS.

Unequalled for CYLINDERS and VALVES and MACHINERY requiring a GOOD LUBRICANT. No ACID, No OXIDATION, UNIFORM in Quality, and ALWAYS LIQUID. The CHEAPEST, BEST, and MOST DURABLE Lubricating Oils in the Market.

WIRE ROPE, TRAM & IMPROVED LOCO. GREASE MAKERS

PETROLEUM, GASOLENE, COLZA & OLIVE OIL IMPORTERS.

JOHN WHEELDON AND CO.,

COTTON MILL OIL AND GREASE WORKS,

AGENTS] **SHEFFIELD.** *[WANTED*

THE COLLIERY GUARDIAN ALMANACK is published ANNUALLY as a Supplement to the *Colliery Guardian*, and copies may be had separately, mounted and varnished, with rollers, for office use, 1s.; carriage free in the United Kingdom 1s. 6d. Unmounted sheet 2d. The ALMANACK contains valuable statistical information as to the Produce and Export of Coal and Iron in the United Kingdom and throughout the World; Names and Addresses of Inspectors of Mines; together with Useful Rules and Tables, Astronomical Notes and Postal and General Information.

Colliery Guardian Office, 49, Essex-street, Strand, London, W.C.

The Colliery Guardian,

AND JOURNAL OF THE COAL AND IRON TRADES.

A GENERAL COMMERCIAL NEWSPAPER,

PUBLISHED WEEKLY IN TIME FOR FRIDAY EVENING'S MAIL.

Price 5d.; by Post, 6d. Per Annum (post free), 24s.

SENT POST FREE FOR ONE GUINEA PER ANNUM,

IF PAID IN ADVANCE AT THE OFFICE.

THIS newspaper was established in the year 1860 for the specific purpose of representing the COAL AND IRON TRADES of Great Britain. It is the property of a large and influential Company of Colliery Proprietors and Ironmasters, who represent many of the largest and most important Coal and Iron Works in the Kingdom. It is the recognised organ of the COAL AND IRON TRADES. Its Subscribers comprise nearly all the Proprietors, Managers, and Agents of Collieries and Ironworks in the United Kingdom, and include also a very large proportion of the upper class of Officials entrusted with the management of the various departments of Coal-mining and Iron-making. It also circulates largely amongst gentlemen engaged in scientific pursuits, and in the various branches of manufacture and commerce.

ADVERTISEMENTS

Are inserted in the COLLIERY GUARDIAN at the following rates:—Three lines and under, 3s.: every additional line, 6d. The line averages eight words.

Contract Advertisements at 3s. 6d., 3s., and 2s. 6d. per inch in single column for 13, 26, and 52 Insertions respectively.

Cheques and Post Office Orders should be made payable to
H. KIRBY ATKINSON, *Publisher.*

OFFICES: 49, ESSEX STREET, STRAND, LONDON, W.C.

WORKS

Published at the "Colliery Guardian" Office, 49, Essex-street, Strand, Lond

Crown 8vo, cloth, lettered, price 3s., post free 3s. 2d.

THEORY AND PRACTICE OF VENTILATING COAL M
by W. FAIRLEY, M.E., F.S.S., being a Reprint, in a convenient form, o
which appeared in the *Colliery Guardian*.

Crown 8vo, cloth, lettered, price 2s. 6d., by post 2s. 8d.

CRITICISMS ON STATIONARY STEAM BOILERS, d
especially to Matters of Construction, Tests of Quality, and to the Discri
Choice of Boilers. By W. MORGANS, F.G.S., Civil and Mining Engineer, author
Manual and Atlas of Mining Tools," &c. Reprinted from the *Colliery Guardian*,
substance of special lectures delivered at the Bristol School of Mines in 1880.

Post free, 6d.

MAP OF ENGLAND AND WALES, SHOWING LIN
EQUAL MAGNETIC DECLINATION for 1885. Reprinted from the
Guardian of the 18th January, 1885. A rule given on the Map enables any st
correct the figures to present or future date.

Crown 8vo, price 2s., by post 2s. 1d.

A PRACTICAL TREATISE ON THE GASES MET
in COAL MINES and the General Principles of Ventilation. By the
ATKINSON, Government Inspector of Mines for the County of Durham.

Price 2s. 6d. 4to.; post free, 2s. 7d.

FAULTS IN THE BRISTOL COALFIELD, & HOW CA
WITH SPECIAL REFERENCE TO LATERAL PRESSURE. By
COSSHAM, Esq., Coalowner. A Lecture delivered at the Bristol Mining School,
3rd, 1879, and reprinted from the *Colliery Guardian*, with numerous sections.

Crown 8vo., cloth lettered, 5s.; post free, 5s. 2d.

HANDBOOK TO THE EXAMINATIONS FOR COL
MANAGERS. By ALFRED J. G. SWINNEY.

A correct and concise treatise on every subject from which questions may be
given, and at the end of each part will be found copies of some questions, with a
the same, which have been given at past examinations, as examples. The simples
Rules and Formulæ for solving matters connected with Mining are given. A
also devoted to the necessary qualifications, &c., requisite at several of the
examination, besides a few remarks on the most desirable method of training and
the examinations.

Crown 8vo., price 3s.; post free 3s. 2d.

THE COLLIERIES, COALFIELDS, AND MINERALS O
SOUTH WALES, AUSTRALIA. By ALFRED J G. SWINNEY, autho
book to Examinations, &c. CONTENTS:—Part I.—*Coal.*—Geology of Coalfield: d
and particulars of all Collieries; their Situation; Map of Coalfield, and 13 sectio
ings, Sinkings, &c.; Labour Question and Rates of Wages, &c., &c.—II.—*Iron.*—
mation as to the principal known Deposits and their Qualities; Iron Mines and
at present opened, &c.—III.—*Tin.*—Where and how found; Washing and Smeltin
sis of Ores, &c.—IV.—*Copper.*—The Cupriferous Localities; account of leadi
Richness of Deposits; several Assays of Ores, from various districts, &c.—V.—
Lead.—and VI.—*Gold.*—The occurrence of these Minerals geologically considered; i
facts as to results of Working; demand for Capital and Labour, account of
Assays, &c.

Seventh Edition, much improved, price 3s; post free. 3s. 2d.

HOPTON'S CONVERSATIONS ON MINES, BET
FATHER AND SON. The additions to the Work are near 80 page
information, principally questions and answers, with a view to assist applicants
to pass an examination as mine managers, together with tables, rules of me
and other information on the moving and propelling power of ventilation, a sub
has caused so much controversy.

Cloth limp, price 1s. 6d.; post free, 1s. 7d.

THE COLLIERY READY RECKONER AND WAGES C
LATOR. By JAMES IRELAND. "Will be the means of preventing mar
between pay clerks and colliers."—*Mining Journal.*

Reduced price, cloth 3s. 6d.

A MINE RENT READY RECKONER, OR TABLE
Facilitating the Calculation of Mine Royalty, Way-leave Rent, &c., at
£1 to £200 per foot per Cheshire acre of 10,240 square yards, concluding wi
showing the Rate per ton, at Rents extending from £5 to £200 per foot, and
varying from 2,200 to 3,800 tons per foot per Cheshire acre; giving, also, the weigh
foot and per cubic yard. By JOHN TARBUCK, Colliery Manager and Surveyo
Colliery Guardian Office, 49, Essex-street, Strand, London, W.C.

Price 1s. 6d.; *post free*, 1s. 7d.

COAL AND IRON TRADES. BY THOS. STUBBS, JR., C.M. Being a review in eight chapters, dealing with the trades' progress during 100 years, also with future prospects.

Demy 8vo., *cloth lettered*, 10s. 6d.; *post free*, 10s. 10d.

REFERENCE BOOK OF PRACTICAL AND SCIENTIFIC INFORMATION for the use of Colliery Managers, by W. WARDLE, M.E., C.C. The work contains a large number of new Rules and Formulæ for working out the problems both practically and scientifically relating to Mining and Engineering.

Crown 8vo., *cloth lettered*, *price* 2s. 6d., *post free*, 2s. 8d.

NOTES ON COAL MINING, BY TREVOR F. THOMAS, CERTIFICATED COLLIERY MANAGER. Intended as an assistance to Candidates for Certificates of Competency as Colliery Managers, and as a useful reference book for Colliery Managers and Mining Engineers.

Colliery Guardian Office, 49, Essex Street, Strand, London, W.C.

FRICTION CLUTCHES
for HAULING GEAR.

Best and Cheapest ever introduced.
Extensively used in large Collieries.
Illustrated Circular Post Free on application.

TURNED WROUGHT IRON PULLEYS.
CHEAP, STRONG, TRUE.

J. BAGSHAW and SONS, Engineers,
BATLEY.

"KING'S HOOK,"
WITH PATENTED
"Automatic Lowering Arrangement,"
Whereby, in case of an overwind, the Hook and Cage can be lowered the moment the Winding Rope is brought back to the Hook again.

ROPE ATTACHMENTS
(KORTUM'S PATENT)
Consisting of Conical Caps and INTERNAL GRADUATED GRIPPING WEDGES
Specially adapted for Winding, Hauling and Driving Ropes.

BLASTING PLUGS,
For Mining, Quarrying and other purposes.

STEPHEN HUMBLE,
5, Westminster Chambers, London, S.W.

SCHIELE'S VENTILATO

C. SCHIELE & CO., (The Union Enginee Co.), 2, Clarence Buildings, Booth-St., Manche

undertake the construction and erection of their Mr. Schiele's Ventilating FANS on Mr. Hugh Penman's system. They have Ventilators now running in all the Coalfields of this kingd sizes varying from 25,000 up to 300,000 cubic feet of minute. The Machines are in a measure self-contained, and need costly erections in brickwork or masonry. The FANS designed and constructed as to be safely capable of a very con able increase of speed over and above their normal working v to meet any emergency. The Engines are of a special type— or double, and are connected either by Broad Belt, Ropes, or from Crank Shaft. Under certain suitable conditions a special is designed for working underground.

Messrs. C. SCHIELE & Co., are the Sole Proprietor Makers of the above type of Ventilator, and have er them in all the Coalfields of this country.

They also make for the purpose of supplying Air in Sinking Pits, for H Out and for Drift-Driving, a special type of FAN, which is constructed so a used either to force air in or to exhaust. The FANS of this class are entire contained, and sent away in one piece ready for bolting down to timbers or stone seat. The quantity of air produced depends on existing conditions, whic The following list shows the quantity each size of these smaller FANS is cap discharging at the FAN'S Mouth:—

Size.	Cubic feet of air per minute.	Diameter of Pulleys.	Weight.		
		in.	Cwt.	qrs.	lbs.
1	2,000	3	2	1	0
1A	4,000	3½	4	1	10
2	6,000	4	7	2	0
3	10,000	6	15	3	0
4	15,000	9	31	0	0
5	20,000	12	56	0	0

Special separate Engines for driving any of the above smaller sizes quoted for on application.

TURBINES.—A special form of high pressure Water Turbine is also for developing water-power in Pits, when available, for driving fans or any suitable Machine.

All enquiries should be addressed to:—

Messrs. C. SCHIELE & C

(THE UNION ENGINEERING CO.),

2, CLARENCE BUILDINGS, BOOTH STREE

MANCHESTER.

BLACK, HAWTHORN, & CO.,

GATESHEAD-ON-TYNE,

SOLE MANUFACTURERS OF

COCKSON'S

PATENT IMPROVED GUIBAL VENTILATOR.

Large Volume—High percentage of useful effect—
and practically no vibration.

Actual result obtained in average working, 250,000 cubic feet of air per minute, with 5 in. of water gauge, by a 30 ft. Fan, at the "Dairy" Pit, Wigan.

ALSO MANUFACTURERS OF

TANK LOCOMOTIVES all sizes and types.



WINDING, HAULING, AND PUMPING MACHINERY,

AND

GENERAL COLLIERY PLANT.

PRICES AND SPECIFICATIONS O